A STUDY OF RAW MATERIAL BEHAVIOUR AND LITHIC TECHNOLOGY WITH SPECIAL REFERENCE TO PENINSULAR PALAEOLITHIC

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CERTIFICATE

This is to certify that the thesis entitled **"A STUDY OF RAW MATERIAL BEHAVIOUR AND LITHIC TECHNOLOGY WITH SPECIAL REFERENCE TO PENINSULAR PALAEOLITHIC"**, *submitted by Mr. Jinu Koshy, for the award of the degree of* **DOCTOR OF PHILSOLOPHY** *in* ***History and Archaeology*** *of the Karnatak University, Dharwad, is a record of independent and original work carried out by him under my supervision and guidance.*

The Thesis or a part thereof has not been previously submitted for any other degree of diploma of this or any other University.

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DECLARATION

I do hereby declare that the thesis entitled **"A STUDY OF RAW MATERIAL BEHAVIOUR AND LITHIC TECHNOLOGY WITH SPECIAL REFERENCE TO PENINSULAR PALAEOLITHIC"** *is a record of independent research work carried out by me under the supervision and guidance of* ***Prof. Ravi Korisettar,*** *Department of Studies in Archaeology, Karnatak University, Dharwad.*

The thesis or a part thereof has not been previously submitted for any other degree to this or any other University.

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Chapter-1

Introduction

Introduction

Research on Palaeolithic archaeology has historically been and to a large extent remains; it is dominated by the lithic artifacts analysis, which forms the majority of evidences. The use of stone tools made a very big breakthrough in the intellectual and technological development of the mankind. Controlled use of firing technique and the invention of tool making technology are the two major technological innovations that what has greatly affected the course of past human development. Flintknapping is said to be an important invention, it's just because it appears first in the archaeological record, mentioning that it could have been adopted to modify "rocks" and to produce tools. Hence, this greatest advancement in the tool making technologies were allowed them to adapt and begin to control the environment. (Where as, in the animal world, the creatures like chimpanzees, sea otters or Egyptian vultures has been observed using "rocks to adopt" as tools, in their unmodified natural forms). These stone tools were used for a very long time in human history and therefore they provide a good opportunity to learn about the temporal changes in the "Human Behavior", as represented by various changes occured in technology and utilization of tools. Hence for this reason, archaeologists attempted to learn as much as possible about "Hominid Behavior" from the analysis of lithic artifact.

Many archaeologists and scholars deemed that these stone tools, as one of the sign for the emergence of culture in hominid evolution. Human tool use has a long and fascinating history, and technological systems are often the focus of archaeology because they may help in the explanation of change in the past. Since technology does establish a range of ecological and economic possibilities for any human society, the idea of tools as influential movers in human origin.

1.1. Phases and terminology used in Palaeolithic studies

Stone tools from the Palaeolithic, the Old Stone Age, turned up sporadically in Britain and spread elsewhere, but their importance went unrecognized. One such was a handaxe made on flint found by John Conyers *c.* 1690 in a gravel pit at Gray's Inn Lane near London with elephant (perhaps mammoth) bones. At this time it was assumed that this handaxe to be a weapon used by the Briton to kill an elephant

brought over by the Romans in the reign of Claudius (Cambridge, Encyclopedia of Archaeology).

By mid-seventeenth century a firmer idea of prehistory was established, this was evident in the work of the 'Pre-Adamites' and 'Antediluvians' like Isaac Lapeyrere who published a book in 1655 called *A Theological System upon that pre-supposition that Men were before Adam*, which argued that 'thunderbolts' (handaxe) were artifacts of an ancient pre-Adamite race.

During the mid-nineteenth century search for Palaeolithic remains had began in Europe with the discovery of flint axe along with animal fossil remains from ancient gravels of the river Somme in France by Jacques Boucher de Perthes in 1836 and published his collection and finding in the first volume of *Antiquités celtiques et antédiluvienaes* in 1846 and was officially accepted by Hugh Falconer (Scottish geologist), Joseph Prestwich (British geologist), John Evans (British archaeologist) and Lyell (president of Geological Section of British Association for the Advancement of Science) in 1858. By this time (mid-nineteenth century) the growth of scientific archaeology was intensified against the Biblical theory of origin of mankind with the discovery of flint axe by Jacques Boucher de Perthes in 1836, the publication of *The Origin of Species* by Charles Darwin in 1859 and the work *The Antiquity of Man* by Charles Lyell (1863). Approximate dates for the Palaeolithic period (Old Stone Age) of the prehistoric past were thus established, although the expression "Palaeolithic" was not used until John Lubbock coined it in his book *Pre-historic Times* (1865) based on the degree of sophistication in the fashioning the tools.

In the last quarter of the 19th century remarkable Paleolithic discoveries were made in France and Spain; these included the discovery and authentication of actual works of sculpture and cave paintings from the Upper (later) Paleolithic Period (*c.* 30,000–*c.* 10,000 BC). When Marcellino de Sautuola discovered the cave paintings at Altamira, Spain (1875–80), most experts refused to believe they were Paleolithic; but after similar discoveries at Les Eyzies in France around 1900, they were accepted as such and were recognized as one of the most surprising and exciting archaeological discoveries. A succession of similar finds has continued in the 20th century. The most famous of these paintings was at Lascaux, France, in 1940.

In Europe, Breuil (1912) conceptualized the Upper Palaeolithic, hence the earlier remaining developments were the 'Lower' Palaeolithic, which in turn was further segmented, introducing a 'Middle' Palaeolithic subdivision. Later, in 1928, John Goodwin and Clarence van Riet Lowe published a seminal work in 1929 which has influenced African archaeology ever since. The work entitled *Stone Age Cultures of South Africa*, Goodwin and Van Riet Lowe (?) proposed that the Stone Age sequence be subdivided into the Early, Middle and Late Stone Age. By proposing their alternative scheme to the European sequence of Lower, Middle and Upper Palaeolithic, Goodwin and Van Riet Lowe were emphasizing the distinctiveness of the African archaeological temporal sequences and typological assemblages.

The post-Second World War period witnessed the beginnings of a major overhaul of the archaeological discipline. The classificatory schemes outlined above for Africa and Europe were taken a step further and recombined by J.G.D. Clark on the basis of dominant lithic technologies. His resulting modes of technology divide the history of stone tools into five Modes (Clark 1968, 1977). The model, with the exclusion of Mode 3, had subsequently applied relatively uncritically by Foley and Lahr (1997) to the African archaeological record. Clark's technological modes supplied them with the framework required to "provide a coarse-grained means of comparing technologies across large regions and through evolutionary time" (Lahr and Foley 2001, 25). The modes are held to be reflective of raw material availability, functional differentiation and manifestations of hominid technological strategies.

Table 1.1.1 Outlines the current status of lithic mode recognition and classification.

Technological mode	Industry and *fossiles directeurs*
Mode 1	Oldowan, Early Stone Age (choppers and flakes)
Mode 2	Acheulian, Early Stone Age (bifacial hand-axes)
Mode 3	Middle Palaeolithic, Middle Stone Age (prepared cores, points)
Mode 4	Upper Palaeolithic (retouched blades)
Mode 5	5 Mesolithic and Late Stone Age (microlithic composite flakes and blades)

After (Clark 1977; Foley and Lahr 1997)

1.2. An outline of terminology used in Indian Palaeolithic period

Pre-historic investigations in the archaeologically rich country like India was begun by Robert Bruce Foote in the last quarter of 19th century with the discovery of handaxe from ferruginous lateritic gravel in Pallavaram (R. B. Foote 1866), even before this, isolated finds of stone tool had been recorded in several parts of India. Robert Bruce Foote found many such sites from Peninsular India and grouped these lithic artifacts into a single heading 'Palaeolithic, or rude stone, age'. After Robert Bruce Foote's death, finds of Palaeolithic sites continued to be made from other parts of India, and further systematization of Palaeolithic period began to be felt.

During the mid-nineteenth century in answer to the systematization of Palaeolithic period, L. A. Cammiade and M. C. Burkitt (1930) divided the pre Neolithic cultures of India into four major groups, namely Series I, II, III and IV and these groups corresponds in general terms to the Lower, Middle and Upper Palaeolithic, and Mesolithic terminology used in Europe.

In view of recent developments in the field of prehistoric study in India, the need for threefold grouping of pre-neoliothic cultures, into large cutting tool industry (consisting of handaxe, cleaver, bifacial & unfacial choppers, pick, kinives and core and flake scrapers), flake industry (consisting of various types of retouched flakes like scrapers, burin, points, knives, borers and awl made from Levallois, Mousterian and from less carefully prepared core techniques) and microlithic industries respectively. So, the most appropriate term for these three groups would be Early, Middle, and Late Stone Age. This was comparable to the terminology used in southern Africa, which was adopted in 1927 (Goodwin and Lowe 1929). This threefold division was originally proposed by Subbarao during (1956,1958) and was proposed and was endorsed by a committee appointed to review the terminology of the Indian Stone Age at the International Congress of Asian Archaeology in New Delhi in December 1961.

1.3. Evolutionary History of the Stone Tools

From over 2 million years lithic artifacts provide a rich and durable source of information about the behaviour of extinct hominids, providing more information on the fossil evidence. Two types of approach was used by the archaeologist to answer

the above question are the phylogenetic and historical approach and the adaptive function approach (R. Foley and Marta M. Lahr 2003).

Phylogenetic and historical approach

More than hundred and fifty years the human evolutionary history was reflected in the stone tool typology. Stone tool typology could be seen to reflect the stages of human history, from simple flake and cores through to more advanced tools like Solutrean point from Europe. In this approach generally it was seen that if lithic assemblage were similar, then they were made from same sort of people and from same culture, depending on the time scale involved; and level of sophistication or complexity of the stone tools reflected the cognitive or cultural status of population concerned usually more or less advanced within the framework of the time (R. Foley and Marta M. Lahr 2003). This approach became formalized in the schemes of Breuil (1912), Burkit (1932), and Bordes (1961).

Adaptive function approach

This kind of approach became popularized by recent archaeologists like L.R. Binford (1973) and K. Schick and N. Toth (1993). The variability in lithic assemblage reflects the demands of the environment and the response of the populations to those demands within the constraints of raw material availability rather than reflecting the social and cultural grouping of the populations who made them as seen in phylogenetic and historical approach. The basic adaptive function of social learning is an enhanced ability to respond to temporal and spatial variations in the environment. In many respects, human culture is nothing more than a straightforward adaptation to climatic deterioration. To this approach a strong ecological approach has been added, that of the constraints of raw material and the process of knapping itself (Crabtree 1966). The ways in which stone tools are made are also considered in this approach. Fortunately, modern flintknappers have rediscovered many of the techniques used by the hominids for the creation of stone artifacts. The study of modern-day craftsmen is tremendously important for understanding the fundamental behavioural processes that lie behind tool production and that are responsible for observable artifact morphologies. Recently it has been argued that differences among typological elements are the result of different

degrees of reduction (for example Dibble argued that continuous retouch over time period will transfer double side scraper into convergent scrapers).

1.4. Palaeolithic technology and human evolution

Palaeolithic period encompasses the first widespread use of technology in human technology and the spread of hominids from the savannas of East Africa to the rest of the world. It ends with the development of agriculture, the domestication of certain animals.

The most abundant remains and the oldest traces of human activity of Paleolithic cultures are a variety of stone tools whose distinct characteristics provide the basis for a system of classification containing several tool making traditions or industries (e.g., Lower, Middle and Upper Palaeoithic). The hominids (first humans) from Late Pliocene and Pleistocene period of geological times used sharp stones as tools. "The emergence of a flaked-stone technology during the course of hominid evolution marks a radical behavioral departure from the rest of the animal world and constitutes the first definitive evidence in the prehistoric record of a simple cultural tradition, or one based upon learning. Primate studies of tool use by our immediate ancestor imply that making and manipulating simple tools is not unique to humans; this observation, however, has not negated the assumption that tool manufacture somehow was profoundly important in the Pliocene context of early hominid evolution, in which the oldest stone artifacts were made. Archaeological evidence shows a gradual increase in the complexity of hominid stone technology over time since its earliest beginning 2.5 million years ago (mya).

Human tool use has a long and fascinating history, and technological systems are often the focus of archaeology because they may help in the explanation of change in the past. Since technology does establish a range of ecological and economic possibilities for any human society, the idea of tools as influential movers in human origin. Stone tools became the mechanism by which humans adapted to changing environmental conditions.Archaeologist and palaeoanthropologist assume that stone tools were made by the first members of our own genus, *Homo* rather than the australopithecines, for it is in the genus *Homo* that we first see a number of trends probably started like expansion of the brain, modification of female pelvis to accommodate bigger-brained babies, and reduction in the teeth, face, and jaws. Even

though stone tools are found at various sites in East Africa before the time of early *Homo* appeared. But the fact is that none of the earliest stone tools is clearly associated with early *Homo*, so it is impossible as yet to know who made them. Susman (1994) has studied the thumb bones and attached musculature of robust australopithecines from 2.5 million years old fossil records and concluded that these hominids found after 2.5 million years had a thumb capable of tool -making. Hence all of them may have been toolmakers (Susman 1994). Recently, intensive archaeological survey, and systematic excavation at Gona in Ethiopian Rift Valley (Africa) led to the discovery of well-flaked stone artifacts dated between 2.6 million to 2.5 million years ago (Susman 1994; Semaw et al. 1997). Currently this is the oldest known Late Pliocene evidence of stone tools used by the hominid and these stone tools are included in the Oldowan Industrial Complex. A nearby contemporary deposit at Bouri in the Middle Awash has brought insights to the function of these simple artifacts by yielding evidence of bones with stone-tool cut-marks and hammerstone facture dated to 2.5 million years ago (de Heinzelin et al. 1999). Another important finding from this site is of *Australopithecus garhi*, the new hominid argued to be the species responsible for making the earliest stone tools (Asfaw et al., 1999). Several species of "robust" *Australopithecus* (*A. garhi*, *A. aethiopicus*, *A. boisei*, and *A. robustus*) were associated with the Oldowan industrial complex (de Heinzelin et al. 1999; Wood & Richmond 2000). These early stone tools called Oldowan stone tool industry, was named and defined from examples excavated from Bed I and Bed II at Olduvai Gorge in Tanzania (Leaky 1971). These simple stones tool had witnessed little change during there life span from 2.5-1.5 million years. The main artifact types found in all of the archaeological sites dated between 2.6 million to 1.5 million years are cores, whole and broken flakes, angular and core fragments, a small number of retouched pieces and in some instances unmodified stones transported to sites. Typologically these stone tools were categorized as core choppers, discoids, flake scrapers and polyhedrals (Leakey 1971). Replication studies throw much light on these stone tools, and were considered to represent a continuum of flaking, and not necessarily target designs (Toth 1985; Potts 1991). The makers of these stone tools possessed an excellent empirical understanding of the mechanical properties of lithic raw materials, and fracture mechanics which gave hominid to adapt the changing environmental conditions around 2.5 million years ago, a time marked by extensive northern

latitude Arctic glaciations, triggering great changes in terrestrial biomass, including the tropics. The Sahara expanded in area, and open and desertic environments and appearance of grassland in eastern Africa with reduction in temperature and rainfall (Clark 1959; Vrba 1996). The Oldowan lasted for over 1 million years with little or no technological changes and it was later replaced by an advanced stone working tradition known as the Acheulian c. 1.5 million years in Africa (Asfaw et al., 1992; Clark 1994; Gowleth 1988; Isaac and Curtis 1974).

The technological innovation and maturation of the Acheulian Industrial Complex (Mode 2) represents the intellectual success of Lower Pleistocene hominids and extended up to Late Middle Pleistocene, when a more evolved technology is found (Clark 1994). Acheulian, the name derives from St. Acheul, France, from where handaxes were first described in the nineteenth century (Boucher de Perthes 1857; Evans 1863; de Mortillet 1893). The earliest Acheulian sites are found in East Africa at approximately 1.6 to 1.4 million years ago and continued until approximately 0.3 million years ago (Asfaw et al. 1992 and Clark 1994), and is associated with three different hominid species (*Homo erectus*, *Homo ergaster*, and archaic *Homo sapiens/Homo heidelbergensis*). It is found first in Africa, and later in western Asia, Europe, and the Indian sub-continent. It is widely assumed that most Acheulian assemblages were manufactured by populations of *Homo.erectus*, but very few or rarely the Acheulian artifacts are associated with *Homo.erectus*. In Africa, the oldest occurrences of the Acheulian (e.g., Peninj, West Natron, Tanzania (c. 1.4 mya) and Olduvai Gorge, Upper Bed II (c. 1.15-1.2 mya Olduvai middle Bed II) are in the time range of *Homo.erectus*. During the Early Pleistocene, population of *H. erectus* seems to have been distributed widely across the temperate areas of Africa. During 1 Ma this species might have passed through Levant into western Asia, from here to other parts of the world. Fossil evidence from Southeast Asia (e.g., China and Java) suggests that *Homo erectus* were present during the Middle Pleistocene period. Some scholars prefer to emphasize on the view that the name, *Homo erectus*, should be retained to the Asian fossil and the hominid from eastern African fossils should be placed in the species of *Homo eraster*. But after 7, 00,000, Acheulian artifacts also occur in sites from Tanzania, Ethiopia and South Africa which are associated with archaic *Homo sapiens*. In Europe Acheulian artifacts are associated with early *Homo sapiens* and are dated

back to 0.5 Ma. Moreover, examples of bifaces from Africa, Europe and Asia are remarkably similar to one another, despite the great distances and time variation between places. With a few exceptions in China and Korea, Acheulian-like industries do not occur east or north of the "Movius Line", which arcs from the Indian-Bangladesh border to northern England. The Acheulian is distinguished form from the Oldowan and Developed Oldowan by the presence of large cutting tools (LCTs) like, handaxes, cleavers, knives, and picks which are frequently manufactured by direct percussion unifacial or bifacial flaking of large (>10 cm) cobbles, flakes, and slabs (Harris 1983; Isaac 1969, 1982; Leakey 1971, 1975; Toth & Schick 1986). Acheulian artifacts may have originated by gradual transition in the degree to which oval-shaped cobbles were flaked (chopper→ protohandaxe→ handaxe) (Delson *et al.* 2000). Acheulian tools types are assumed to reflect arbitrary preconceived designs imposed on a diverse range of primary forms, unlike Oldowan stone tools, whose shapes are largely controlled by the primary form, size, and mechanical properties of raw materials (Isaac 1986). Geographical and chronological handaxe retained the same shape, typically a teardrop-shaped plan form with a lenticular cross section with bilateral symmetry and the high degree of standardization of shape over a wide range of sizes imply a well-defined concept of shape and proportion, reflecting higher conceptual and cognitive abilities than in the Oldowan (Wynn 1991, Gowlett 1984). Cleavers have a sharp, thin, usually unmodified edge transverse to the long axis (the cleaver bit). Picks and knives have convergent tips, like handaxes. Picks have a thick cross section at the midline, and knives have one thick lateral margin. Biface forms did undergo refinement over time span of the Acheulian and there is considerable variation in the form and within an assemblage. In order to study the variability within assemblage, morphmetric (Roe 1964) and typological method (Bordes 1961, Kleindienst 1962) based on plan form was used. Isaac followed Roe's method of work, and made a little modification (Isaac 1977). However, the meaning of variation in the frequencies of classes and subclasses and in the sizes and shapes of LCTs between sites is indistinct. The shapes of LCTs are usually assumed to confirm to the mental template of the cultural group. If so, LCT style can be used to identify regional cultural traditions (Wynn & Tierson 1990). Evaluation of the existence of style with Isaac's (Isaac 1986) five-step "method of residuals" (MR), which systematically examines noncultural influences on form first and cultural ones last, suggests that mechanical

properties (Jones 1981, Noll 2000); the abundance, size, and shape of available raw materials; the primary form of the blank (flake, cobble, or slab) (Noll 2000); and the amount of resharpening done (Noll 2000, McPherron 2000) account for most interassemblage differences in form modalities. Finished artifact forms may thus be the unintended byproduct of several non-stylistic factors rather than intended target types. Microwear studies show that LCTs may have been multipurpose tools (Keeley 1980). Experiments show that they are excellent for heavy-duty butchery, woodworking, and other tasks (Keeley & Toth 1981; Jones 1981).

During the later Acheulian, LCTs became more refined in shape and adding variety of forms to the assemblage. This was due to the use of soft hammers of hardwood or bone, which make straighter edges and more regular plan forms (Clark 1994). However, refinement does not always correlate with age, because poor raw materials produce unrefined artifacts (Jones 1981, Noll 2000). The late Acheulian technology is usually associated with H. *heidelbergensisi*/archaic *Homo sapiens* from all over the world. New strategies of tool manufacture and regionally distinct industries appeared at the end of the Acheulian, around 0.3 to 0.5 Ma (McBrearty & Brooks 2000). Cores were carefully shaped by variants of the Levallois prepared core technique (named after a suburb of Paris) to produce very large flakes that were close to the finished form, and blades were struck from prismatic cores (McBrearty & Brooks 2000, Jelinek 1990).

The period of cultural history associated with flake tools is traditionally called the Middle Palaeolithic in Europe and the Near East and dates from about 300,000 years to about 40,000 years ago. In Africa, instead of Middle Palaeolithic, Middle Stone Age is used. The Middle Palaeolithic/Middle Stone Age are defined both technologically and chronologically as being intermediate to the Lower Palaeolithic and Upper Palaeolithic based on the observation from Europe, Africa and Asia. In this period technological and cultural evolution accelerated. Stone tools manufacturing developed a more sophisticated tool-making technique known as the prepared-core technique (like Levallois and Disc Core technique) from the earlier core tool technology (Acheulian), which permitted the creation of more controlled and consistently desired flakes and an increase in the size and complexity of retouched flake tools. The Middle Stone Age shows traces of 'cognitively modern' behavior, which is often visible in the technological, socio-economic and symbolic

fields (Clark, 1989, 1993; Hayden, 1993; McBrearty, 1993; McBrearty and Brooks, 2000; Foley and Lahr, 2003; Henshilwood and Marean, 2003). The Middle Palaeolithic period also witnessed improvement in hunting technology and hunting abilities reflected both in the tools and in the faunal remains, the first sustained occupations are witnessed in the form of repeated occupation of rockshelters and caves, and an intensification of symbolic activities reflected in the first use of colored mineral pigments and the first burial (Delson *et al.* 2000) and some engraved or scraped pieces of ochre like those found in Blombos Cave in South Africa (Jinu give some more examples) (Henshilwood *et al.*,2001) suggest a link between the level of symbolic activities and the evolution of modern Behavior (Henshilwood and Marean,2003).

Recent palaeoanthropological syntheses indicate that the Middle Stone Age of Africa may coincide with a variety of key evolutionary events, including the emergence of modern human morphology, the development of more complex adaptation, and the dispersal of modern humans outside of Africa (Foley & Lahr 1997; McBreaty & Brooks 2000).These MSA technologies were associated with a new species *Homo helmei* (Foley & Lahr 2003). During the terminal Middle Pleistocene and the earlier parts of the Upper Pleistocene show the evolution of highly encephalized and derived forms of hominids, Neanderthals (*H. neanderthalensis*) in Eurasia and modern humans (*H. sapiens*) in Africa (Stringer 1995). Neanderthals and modern humans may have shared a more recent Middle Pleistocene ancestor than *H. heldelbergensis* probably *H. helmei* (Foley & Lahr 1997).

Neanderthal species are associated with Mousterian culture and their remains are found from Europe, North Africa, Palestine, and Siberia. A strong consensus has emerged regarding their evolutionary entity, that the now-extinct Neanderthals were a distinct from modern humans, presumably a different species. They were archaic members of the human family, robust with heavy brow ridges and forward-projecting faces, which lived in Europe and western Asia from at least 250,000 years ago until they vanished from the fossil record about 28,000 years ago. Artistic expression emerged for the first time, with ochre might have been used as body paint and some early rock art appearing. There is also some evidence of purposeful burial of the dead, which may indicate religious and ritual behaviours. The next species

which were using the Middle Paleolithic technology were the latter, *H. sapiens*., and these *H. sapiens* are present in Africa more than 150, 000 years ago, but occur, presumably through population expansions, in other parts of the world considerably later: 100, 000 years ago in Western Asia, 60,000 years ago in Australia, and around 40,000 years ago in Mediterranean Europe and Eurasia (Lahr & Foley 2001). Based on the both the technology present and the morphology of the associated hominids (i.e., modern humans), the MSA were initially judged to be equivalent to or contemporaneous to the Upper Paleolithic of Europe (Klein, 1970:132). This interpretation was reinforced by erroneous radiocarbon estimates (see Klein 1970: Table 1). Sampson (1974) reassessed the MSA as equivalent to the European Mousterian on broad chronological grounds. And, when it became clear that anatomically modern people had much greater time depth in Africa than in Europe, the MSA was broadly accepted as essentially equivalent to the European Middle Paleolithic (Klein 1999). McBrearty and Brooks (2000) also convey eloquently a countering view to that forcefully proposed by Klein and others that even if the African hominid record is much deeper, much of that depth has no relevance to the origin of modern humans and this was reinforced by an anthropologist Rebecca Cann (1987) and colleagues compared DNA of Africans, Asians, Caucasians, Australians, and New Guineans. Their findings were striking in two respects:

- the variability observed within each population was greatest by far in Africans, which implied the African population was oldest and thus ancestral to the Asians and Caucasians;
- there was very little variability between populations which indicated that our species originated quite recently.

Rebecca Cann concluded that Homo sapiens originated in Africa about 200,000 years ago. Much additional molecular data and hominid remains further support a recent African origin of Homo sapiens, now estimated to be around 160,000-150,000 years ago. The earliest skeletal materials assigned to *H. sapiens* are all from Africa. The oldest skeletal material in the world that has been attributed to *Homo sapiens* are the Omo materials from near Lake Turkana, Ethiopia which has recently been re-dated to 196,000 years ago (McDougall *et al.* 2005). The second oldest Homo sapiens material (which was considered to be the oldest for about a year ago) is from near Herto, Ethiopia and has been dated to between 154,000 and

160,000 years ago (Clark et al. 2003, White et al. 2003). Skeletal material from southern African MSA sites that has been identified as Homo sapiens includes several fragmentary individuals from Border Cave (Beaumont et al. 1978, Beaumont 1980, Morris 1992, Pearson and Grine 1996, Pfeiffer and Zehr 1996, Sillen and Morris 1996) and Klasies River (Singer and Wymer 1982, Rightmire and Deacon 1991, Grine et al. 1998), teeth from Die Kelders (Grine 1998, 2000) and a handful of material from Pinnacle Point 13B (Marean et al. 2004). The dating of this material has long been recognized as problematic, but the application of multiple dating methods has led to a consensus that at least some of the Klasies and Border Cave material is older than 100,000 years and the balance of the Klasies material is older than 60,000 years.

Modern Human Origins

There were, until recently, two major opposing hypotheses for the origin of our species; the "Out of Africa" hypothesis and the "Multi-regional" hypothesis. The "Out of Africa" hypothesis, also referred to (more correctly) as the "Out of Africa 2" (Stringer and McKie 1996) hypothesis (accounting for the at least one earlier *Homo* exodus from Africa), the "African Eve" hypothesis, or the "Replacement" hypothesis, holds that *Homo sapiens* evolved in Africa and nowhere else and then migrated to all other parts of the globe with a little or no genetic contribution from other hominid species and rapidly replaced them. There are several models to explain the timing of this evolution in Africa.

The "Multi-regional" hypothesis holds that *Homo sapiens* evolved in Africa, but through gene flow and hybridization modern peoples in regions of the world outside of Africa retain genetic contributions from indigenous hominids, *Homo erectus* in East Asia and *Homo neanderthalensis* in Europe (Wolpoff *et al.*1984). This hypothesis has a strong form and a weak form. The strong form holds that indigenous hominids made a substantial genetic contribution to regional modern populations; essentially that *Homo sapiens* has been the only hominid species extant since at least 1.8 million years ago and that the modern form evolved in several places at once, through gene flow. Local "archaic" populations made some genetic contribution of some kind to the earliest local anatomically modern ones. All proponents of this model have shifted to increasingly weaker forms as new evidence

is accepted, that makes stronger forms of this hypothesis increasingly unlikely (Pearson 2004).

Archaeological, biological and genetic evidence strongly supports a single African origin. Archaeologically modern behavioural package is witnessed by the emergence backed artefacts made from blade blanks and are related to symbolic activities in Eroupe somewhere around 45ka in Upper Palaeolithic. But this modern behavioural package is seen much earlier in the African record dated to more than 60 ka (e.g. Howieson's Poort in South Africa) with the emergence of modern humans. Many fossil records from Africa are also dated to much earlier dates than from other parts of the world. The genetic evidence strongly supports a single African origin for all peoples living today. It is interesting that the regional ancient *Homo* population that we know the most about genetically, Eurasian Neandertals, now seems the least likely to have made any contribution to living populations. Taken together, the archaeological, morphological, and genetic evidence fit only the "Out of Africa" hypothesis in explaining the origin of our species. What remains to be determined are the where (in Africa), when (during the MSA), why, and how of that event. Recent syntheses on the archaeological, anthropological and genetic evidence on modern humans by Disotell (1999), Foley (1998), Harpending *et al.* (1998) and Jorde *et al.* (1998) supports their recent origin in and spread out from Africa (Stringer & Andrews 1988). Various alternative for the dispersal of modern human have been proposed by many scholars (e.g., Chu *et al.* 1998; Hammer *et al.* 1997; 1998; Jin *et al.* 1999; Kivisild *et al.* 1999a; Lahr & Foley 1994; 1998; Templeton 1997). First the alternative extremes: (i) the northern route, over Sinai, leading to eastern Asia through the steppes of Central Asia and southern Siberia and (ii) the southern route over southern Arabia, followed by the migration along the coastline of southern Asia. While the northern route model could explain the peopling of the whole Eurasia by a single migration from Africa, the southern route model is interpreted as implying at least two separate Late Pleistocene dispersal events, one leading to the northwest and the other to the east of Eurasia (Cavalli-Sforza *et al.* 1994; Lahr & Foley 1994). Regarding the question when did the modern humans dispersed from Africa, many peoples suggested many views, like Klein has argued that the main dispersal of modern humans from Africa probably occurred only after the beginning of the Later Stone Age (equivalent to the Eurasian

Upper Palaeolithic). According to Klein, the presence of modern humans in the Levant during the last interglacial, represented by the burials at Skhul and Qafzeh, was only a brief geographical extension of the species from Africa. The real dispersal of *Homo sapiens* was through that region, but did not occur until the Upper Palaeolithic, perhaps 45,000 years ago (Klein, 1999). Another view put forward by Kingdon (1993) proposed that Middle Palaeolithic people left Africa through the Levant and reached Southeast Asia by 90,000 years ago. There they adapted to coastal conditions, and developed a boat- or raft- building ability that enabled them both to return to Africa and to move southwards to Australia. By contrast, Foley and Lahr (1997) suggest in their 'multiple dispersals model' that a more direct route from Africa to Arabia and further east could have been taken before 50,000 years ago, perhaps using the coast. The findings of Walter *et al.* (2000), together with new data from Australia, allow further elaboration of these possibilities. There is increasing archaeological evidence that Australia was colonized (by boat, because no land bridges existed during the Pleistocene) before 50,000 years ago, that is, before the increase of Later Stone Age and Upper Palaeolithic features such as blade tools and art. Moreover, a modern human burial site from southeastern Australia, associated with the symbolic use of red ochre, has been re-dated to about 60,000 years ago (Thorne 1990). This implies that at least one dispersal of modern humans from Africa must have occurred during the Middle Palaeolithic, and that characteristic elements of modern-human behaviour existed by then.

During the later part of Middle Pleistocene saw the emergence of 'anatomically modern *Homo sapiens*' (AMHS). As previously stated the oldest skeletal remains of *Homo sapiens* are from Omo a site near Lake Turkana, Ethiopia which has recently been re-dated to 196,000 years ago (McDougall *et al.* 2005), and then spread into the Middle East (Qafzeh 120,000±8,000 BP), then into Asia (70,000 BP), Australia (60,000 BP) and Europe (40,000 BP) and eventually into the Americas by 13,000 BP. These modern humans eventually developed a new type of flake tool industry, blade and burin and microlithic technology. In Africa, anatomically modern *Homo sapiens* are associated with MSA as well as Late Stone Age (LSA) and are usually typified by the innovation of blade, backed blades, burin, and microlithic industries and in other parts of the world this technologies are called as Upper Palaeolithic with younger dates.

During 19th century, in Europe, *Homo sapiens sapiens* skeletal remains were found associated with early Upper Paleolithic artifacts at the rock shelter of Cro-Magnon in southern France. The term *Cro-Magnon Man* has thus sometimes been used to refer to anatomically modern humans in the context of the Upper Paleolithic. Not all humans were anatomically modern in this period, however, in the early stages of the Upper Paleolithic, the sites that made the Chatelperronian industry appear to be associated with late Neanderthals, possibly influenced by modern humans arriving with Aurignacian technology. These flake tool type found in Europe and West Asia are called Upper Palaeolithic and Later Stone Age (LSA) in Africa. The Upper Paleolithic extends from approximately 40,000 years ago until the end of the last ice age, about 10,000 years ago. The Later Stone Age in sub-Saharan Africa, where it extended much longer, even to historical times in parts of the continent same kind of phenomena is noticed in India. The first of these industries to appear in the Near East and Europe is known as Aurignacian. Later Upper Paleolithic industries include the Perigordian, Solutrean, and Magdalenian in Europe. The Upper Paleolithic is usually characterized by specially prepared cores from these prepared core *blades* (flakes at least twice as long as they are wide) were struck off with a bone or antler punch and then retouched into various tool types. Upper Paleolithic humans also developed new forms of scrapers, backed knives, burins, and points. Beautifully made, two-sided, leaf-shaped points are also common in some Upper Paleolithic industries of Europe. In the Upper Paleolithic, standardized blade industries appear and become much more widespread than in previous times. By the end of the Upper Paleolithic period and the end of the last ice age about 10,000 years ago, *micorolith* industry (small, geometric-shaped blade segments) became increasingly common in many areas. In Upper Palaeolithic period, fine quality of raw material (stone) for tools production was often obtained from more distant sources, sometimes in larger quantities than seen previously in the Stone Age. Occasionally, stone was traded or carried over several hundred kilometers. It seems likely, therefore, that trade and transport routes were more formalized than they had been in earlier times. The Upper Paleolithic also documents the trade of exotic materials, such as marine shells or semiprecious stones, for personal ornamentation as beads or on necklaces.

During the Upper Paleolithic, tools of bone, antler, and ivory become common for the first time. These tools include points, barbed harpoons, spear throwers, awls, needles, and tools that have been interpreted as spear-shaft straighteners. The presence of eyed needles indicates the use of sewn clothing (presumably of hide and possibly early textiles) or hides coverings their shelters. In some carvings from this period, human figures are depicted wearing hooded parkas or other vestments. Other technological innovations include lamps (in the form of hollowed out stones filled with flammable substances such as oil or animal fat) and probably the bow and arrow (small projectile points have been interpreted as arrowheads). Many Upper Paleolithic artifacts appear to be evidence of composite technology, in which multiple components were combined together to form one tool or process. For example, spear tips were attached with binding material to spear shafts, which were flung using spear throwers. But in Africa, the uses of composite tools have started much earlier, from Middle Stone Age. Upper Paleolithic populations appear to have been competent hunter-gatherers. The use of mechanical devices such as spear throwers and, probably, bow and arrows allowed them to increase the velocity, penetrating force, and distance of projectiles. Many Upper Paleolithic sites contain large quantities of mammal bones, often with one species predominating, such as red deer, reindeer, or horse. It is believed that many of these Upper Paleolithic hunter-gatherers could effectively predict the timing and location of seasonal resources, such as reindeer migrations or salmon runs.

Structural activities during this period

Many Upper Paleolithic sites feature elements that have been interpreted as evidence of housing. These are commonly patterns of bone or stone concentrations that seem to delineate hut or tent structures. The best example is Mezhirich, in the Ukraine, and Kostenki, in Russia, hut structures were found made of stacked or aligned mammoth bones. Distinctive hearths, often lined or ringed with rocks, are much more common in the Upper Paleolithic than in earlier times.

Burial practice during this period

Evidence of human burial is much more common in this period. In addition, burials tend to be more elaborate than in Neanderthal times, often associated with rich grave goods. For example, at Sungir, in Russia, three individuals were buried

with ivory spears, pendants and necklaces of shells and animal teeth, and thousands of ivory beads that had apparently been sewn into their clothing.

Art of this period

The earliest representational art, in the form of painting, sculpture, and engraving, dates back to approximately 32,000 years ago. Sites in Europe are famous for their artwork, but prehistoric Stone Age art has also been richly documented in Africa, Australia, and other parts of the world. Animals are common subjects of Upper Paleolithic art, and human figures and abstract elements such as lines, dots, chevrons, and other geometric designs are also found. Among the hundreds of European sites with Upper Paleolithic cave paintings, some of the best known is Altamira, in Spain, and Lascaux and the more recently discovered (and archaeologically oldest) Chauvet, in France. Animals such as bison, wild cattle, horses, deer, mammoths, and woolly rhinoceroses are represented in European Upper Paleolithic cave art, with human figures relatively uncommon. Later Stone Age paintings of animals have been found at sites such as in Apollo 11 Cave, in Namibia; and stylized engravings and paintings of circles, animal tracks, and meandering patterns have been found in Australia's Koonalda Cave and Early Man Shelter. A number of small sculptures of human female forms (often called Venus figurines) have been found in numerous sites in Europe and Asia. Small, stylized ivory animal figures made more than 30,000 years ago were discovered in Vogelherd, Germany, and clay sculptures of bison were found in Le Tuc d'Audoubert, in the French Pyrenees. In addition, many functional objects, such as spear throwers and batons, were superbly decorated with engravings, sculptures of animals, and other motifs.

The archaeological record of the Upper Paleolithic shows a creative explosion of new technological, artistic, and symbolic innovations. There is little doubt that these populations were essentially modern in their biology and cognitive abilities and had fully developed language capabilities. There is a much greater degree of stylistic variation geographically (some archaeologists have suggested that this is evidence of the emergence of ethnicity) and a more rapid developmental pace during the Upper Paleolithic than in any previous archaeological period.

1.5. Outline of Palaeolithic technology and human evolution of India

Brief outline on the Lower Palaeolithic Culture of India

Evidence for the earliest occupation by humans in Indian subcontinent started with the discovery of Lower/Early Palaeolithic tools from Pallavaram by Robert Bruce Foote (1866). After the discovery of the first Palaeolithic tools from India, many sites yielding Lower Palaeolithic artifacts have been discovered from almost all parts of India and in varied geographical situations. They are found in the foothills of the Himalayas which have semi-temperate climatic characteristics, in desert or semi-arid regions like Rajasthan and Saurashtra, in frosted and hilly regions in eastern India, in costal areas, on river valleys in peninsular plateau regions, near natural rock exposures, rock shelters and in association with detrital laterite gravels. Hominids from the Lower Palaeolithic period thus seen to have adapted themselves to all kind of land forms, despite their regional differences, within the basically monsoonal climate of India. Conventionally, the Indian Lower Palaeolithic has been divided into two 'industrial or cultural traditions' the Soanian and the Acheulian or 'Madrasian'. Soanian industries, found over parts of Pakistan and Northwest India, are dominated by pebble or core tools and are characterized as a predominantly chopper/chopping tools (unifcial and bifacially worked cores deriving from cobble and pebble, and the flakes byproducts were occasionally retouched into tools). Lower Palaeolithic in Indian subcontinent, by and large, is of Middle Pleistocene in age (700 to 130 kya). Older archaeological occurrences, from the late Pliocene and Early Pleistocene, have also been reported from the Indian subcontinent. The stone tools comprising simple cores and flakes (Mode 1) found from Riwat, near Rawalpindi in Pakistan have been dated to 2 million years (Rendell and Dennell 1985; Rendell *et al* 1987), and the Isamapur comprising handaxe and cleavers of Acheulian type (Mode 2) have been dated to 1.2 million years (Paddayya et al. 2002), otherwise most of the Indian Lower Palaeolithic are dated from >150 to >350 kyr. The Acheulian industry is much more wide spread all over Indian than the Soanian tradition. Majority of Soanian sites are found in the Northwestern parts of India. The Acheulian industry in India is characterised by bifacially flaked artifacts like handaxes and cleavers, along with bifacial and unifacial choppers, denticulates, scrapers, spheroids, picks, and polyhedrons amongst other tools. Some times these handaxes are unifacially worked. Indian subcontinent represents the eastern-most

expansion of Acheulean hominins from Africa to other parts of the world. Acheulean sites from peninsular India indicates that population shifted their locations over the course of the Pleistocene. The inferences made form documentation and the plotting the Acheulian site from Hunsgi-Baichbal Valley by Paddayya (2007) indicated that the hominin population may have been rather small, either going extinct in certain areas or shifting their locations between various basins over time (Petraglia 2007).

Many scholars have divided the Acheulian into three Early, Middle and Late/Advance phases, on technological and typological grounds. Early and Late stages of Acheulian have been noticed in India and most of them are of Late Acheulian. Characteristic features of

Early Acheulian are:

- the specimen will be have inferior workmanship, deep and irregular flake scars, thick body, asymmetrical and the absence of the Levallois technique and predominance of handaxes, choppers, polyhedrons and spheroids, and presence of only a few crude cleavers are believed to characterise this earlier phase.

Later Acheulian:

- specimen from Late Acheulian show superior workmanship, shallow, regular flake scars, symmetrical, controlled flaking, different type of handaxe and the high proportion of flake tools, larger number of cleavers, and use of the Levallois techniques.

In spite of large number Lower Palaeolithic artifact unearthed from the excavation and exploration from all over India, there is paucity in the fossil remains form India. The sole fossil evidence of an early hominid from India is of a hominin calvarium, which was recovered from Hathnora in the Narmada valley in Madhya Pradesh, and was named as '*Narmada Man*' (Sonika, 1984; Kennedy, 1999), later a clavicle was also found. Originally classified as a male *Homo erectus* with an unusually large cranial capacity (1260 cc) and a high mental eminence (Sonika, 1984) it has since be reassigned as a female of 'archaic' *Homo sapiens* or what is now known as *H. heidelbergensis* (Kennedy, 1992; 1999). Various dating methods have assigned the sediments in which the fossil occurs to late Middle Pleistocene (Badam *et al.* 1986, Badam, 1984; Rightmire, 2001) or as decendents of an early *H.*

sapiens clade from Europe, with little relationship to Asian *H. erectus* or *H. pekinensis* (Cameron et al., 2004) and significantly this fossil evidence is associated with Late Acheulean artefacts. Morphologically, when all metric traits are considered, it should be considered as *H. erectus*, and when the brain size and "transitional" morphology are considered, it should be classified as *H. heidelbergensis* (Athreya, 2007).

Brief outline on the Middle Palaeolithic Culture of India

Till about the middle of the twentieth century, prehistorians generally thought that in the development of Indian Stone Age cultures there was no Middle Palaeolithic culture comparable to Europe. Till this time, only at a few places, such as Sohan valley and Narmada basin, discovered by de Terra and Paterson in 1939, at Kandivali near Mumbai by Todd in 1938, and in Kurnool district in Andhra Pradesh by Cammiade and Burkitt in 1930, some flake tools, characteristic of the Middle Palaeolithic culture were discovered.

The tools of this culture were, however, also discovered at Nandur Madhmeshwar on the Godavari, Nasik district, Maharashtra in 1943, but doubts still persisted. The credit for the identification of the Middle Palaeolithic culture in India in fact goes to H.D. Sankalia who discovered a flake industry comprising scrapers, points and borers made on siliceous materials like chert, chalcedony, agate and jasper in the stratified deposits (Gravel II) of the Pravara at Nevasa in 1955. He named it 'Series II' of the Palaeolithic artefacts, Series I being the handaxe-cleaver industries of the earlier period. Subsequently, similar artefacts were discovered in different parts of peninsula. As in the early phase of these discoveries, the nomenclature of Indian Palaeolithic cultures was not finally settled, these were ascribed various names like the Middle Palaeolithic, Middle Stone Age, Series II, Nevasian, and Flake Culture by different scholars for the simple reason that it was felt by some scholars in India, including Sankalia, that Indian situation was different from the European, India did not witness the classical European Middle Palaeolithic. However, after a lot of debate, spanning over at least a decade or more, it was agreed that India too had its own Middle Palaeolithic.

The Middle Palaeolithic sites are generally distributed in the same area where the Lower Palaeolithic sites are located, indicating thereby that the Middle Palaeolithic population occupied the same areas and the Middle Palaeolithic culture evolved from the Lower Palaeolithic culture. The Lower Palaeolithic Acheulian culture developed slowly and gradually into the Middle Palaeolithic by shedding some of the older tool types, and also by evolving new forms and new techniques of making them. Dates for this period range from around 1,50,000 to 30,000 before present (BP); a period characterized in general by aridity.

The Middle Palaeolithic culture developed during the Upper Pleistocene, a period of intense cold and glaciation in high altitudes and northern latitudes. Areas bordering glaciated regions, however, experienced strong aridity. That is perhaps the reason why Middle Palaeolithic sites are comparatively sparse in western Rajasthan, the Mewar plateau and the Gujarat plains. But the river valleys of peninsular region had very congenial climate due to which man lived there comfortably.

In India, Middle Palaeolithic assemblages have been reported from Luni valley, around Didwana, and around Budha or Old Pushkar in western Rajasthan, at numerous sites in the valleys of the Chambal, Son and Narmada and their tributaries in Central India, as well as from the Chhota Nagpur plateau, on the Deccan plateau, and the Eastern Ghats.

The Middle Palaeolithic sites are found located in the open-air along perennial as well as seasonal streams, along hill slopes as in Peninsular India, on stable sand-dune surfaces as in western Rajasthan, and in rock-shelters as in central India.

In the flake industries from the Middle Palaeolithic period quartzite is seldom used, and chiefly cryplocrystalline silica of various kinds, often called 'semi-precious stones', such as agate, chert, chalcedony and jasper were frequently used. Two principal methods of obtaining flakes from prepared cores can be distinguished. The first method is that of striking flakes from carefully prepared disc-shaped or oval cores (discoidal core) in the manner common to the Levallois-Mousterian industries and the resulting flakes are round or oval according to the shape of the core. The second method is that of striking triangular, square and oblong flakes from less carefully prepared cores (Allchin, 1963). These flakes in turn were retouched

i.e., by finely trimming the edges of parent flakes by the removal of tiny thin flakes or chips, apparently to strengthen the cutting edge of the tool and made into different forms of tools like scrapers (side and end scrapers), denticulates, notched scrapers, points, burin and borers. In the early phase or the transition (i.e., from Acheulian to Middle Palaeolithic) period, miniature handaxes are found with the flake tools.

Faunal remains from this period consist of wild horse (Equus namudicus}, wild cattle (Bos namadicm) hippopotamus (Hexaprotodon palaeindicus), wild elephant (Elephas hysudricu.v), Stegodon insignia ganesa and Cervus sp. suggest a savannah grassland environment interspersed with swamps and forests. Kalegaon in Maharashtra has yielded extremely interesting evidence where a few stone tools were found embedded in the skull of a wild bull (Bos namadicus), which indicates the function of the tools and their contemporaneity. No human fossil has been found till this date from this period.

Brief outline on the Upper Palaeolithic Culture of India:

The Upper Palaeolithic is the most controversial and least known phase of Indian prehistory. Towards the end of the Pleistocene, around 30,000 years ago, a distinct change in tool types and technology is noted. Culturally, it is characterized by a new lithic tradition of blades and burins although a variety of other types, such as side-scrapers, end-scrapers, hollow scrapers, points, borers, etc. are also found in large quantities. Over most of India, this phase is marked by a very arid climate. However, the Upper Palaeolithic phase in India is neither geologically nor culturally well defined. There are only a few localities where the industries of this phase have been found in stratified deposits. On one end it is the continuation of the Palaeolithic cultures, and, on the other end, it merges with the Mesolihic cultures.

First indirect reference to the existence of Upper Palaeolithic in India was made by Robert Bruce Foote. He claimed to have discovered a few bone implements from Billa Surgam cave in Kurnool and thought them to be comparable to Magdalenian of France (Magdalenian is one of the Upper Palaeolithic cultures of Europe characterized by a large number of decorated bone tools besides tools made on stone blades). Later, Todd reported, one 'Series III,' same as Upper Palaeolithic assemblage, from the stratified deposits at Kandivali, near Mumbai, which is characterised by blades and burins. A few other stray finds have been reported by S.P. Gupta from Jabalpur region, by Malti Nagar from Ahmednagar, Maharashtra

and by K.V. Raman from Madurai district of Tamil Nadu. A good number of artefacts from stratified deposits have been recovered by Issac from Kurnool district, A.K. Ghosh from Singhbhum district of Bihar, G.R. Sharma from Belan basin, M.L.K. Murthy from Chittoor district of Andhra Pradesh and K. Paddayya from Shorapur Doab of the same state.

M.L.K. Murthy and V. Rami Reddy were the first to plead for a well-defined place for the blade-and-burin industry of the Upper Palaeolithic in India. Various scholars however, variously refer to Upper Palaeolithic of India, as Series III / flake-blade / blade-tool / blade-and- burin / Upper Palaeolithic or Upper Palaeolithic-like. However, now the term Upper Palaeolithic alone is wieldy used in preference to the rest of the terms.

The Upper Palaeolithic culture developed during the later part of the Upper Pleistocene. The climate of this period was characterized by extreme cold and aridity in the high altitudes and northern latitudes. Palaeoclimatic research, including geomorphology, sedimentology, and pedology as well as radiometric dating, such as TL and C^{14}, in different parts of India, shows that there was intense glaciations in high altitudes and severe aridity in much of peninsular India, northeast India and the southeast coast. In northwest India, fossil dunes indicate aridity during the Late Pleistocene. Geomorphic evidence indicates that there was a decrease in rainfall and consequent poor vegetation in many parts of the country. In coastal Tamil Nadu, Saurashtra, and Kachchh there was a lowering of sea level around 20,000 years BP.

The Upper Palaeolithic is characterized by the introduction of true blade technology along with the continued use of flake tools. The Bhimbetka Rockshelter III F-23 excavations revealed, in the upper levels, an assemblage of burins, backed blades, awls, points and scrapers. Patne in the Tapi valley should be considered a classic Upper Palaeolithic site - five levels, stratified between the Middle Palaeolithic and Mesolilhic, reveal an advanced development of the indigenous character of this culture.

The Upper Palaeolithic cultures provided a link with the early Palaeolithic technologies, marking a distinct process of maturation of artefacts, which reached its climax in the Microlithic industries of the Mesolithic phase. The upper Palaeolithic tool assemblages show a marked regional diversity with respect to the refinement of

techniques and standardization of finished tool forms. The principal artefact forms in these assemblages are scrapers (side, convex, notch, end, sleep, round, convergent, etc.), flake-blades, blades and cores; backed blade variants (straight back, curved back, backed knives, points, lunates, triangles and trapezes); burins, unifacial, bifacial and tanged points and choppers. Bone tools have also been reported. These have come from the Kurnool caves and the Godavari Khani open-air site in Karimnagar district of Andhra Pradesh. The bone tools from the Kurnool areas recovered by M.L.K. Murthy are described as scrapers, perforators, chisels, scoops, shouldered points, barbs, spatulae, worked bones, bone blanks, broken and cut bones and splinters. Such a rich assemblage of bone tools belonging to the Upper Palaeolithic has not been reported from any other site in India.

Belief System and Art

Continuity of culture from the Upper Palaeolithic to present times is especially seen in the sphere of belief system or religion At the site of Baghor II and in the Son valley archaeologists found rectangular stone rubble platforms with a triangular stone with natural concentric circles located in the centre Similar stones installed on stone platforms are today worshipped as mother goddesses by tribal communities in the area. The Baghor structure probably represented the earliest shrine in India and suggests a remarkably long continuity of mother-goddess worship. Another noteworthy evidence of art for this period is a bone harpoon type figurine (so-called mother-goddess figurine) recovered by G.R. Sharma and his team in the Belan valley in Uttar Pradesh.

Sali reported beads as the first evidence for art in the Upper Palaeolithic levels at Patne in Jalgaon district, Maharashtra. Two beads and two bead blanks were found which were correlated with the Upper Palaeolithic faunal remains. The beads consisted of an ostrich eggshell bead and two blanks of the same material and a marine shell bead. Wakankar reported etched ostrich eggshell fragments at the Upper Palaeolithic site near Bhopal, Madhya Pradesh.

Fossil faunal remains, including *Canis sp.*, *Equus namadicus*, *Elephas sp.*, *Bubalus sp.*, *Cervus sp.*, *Bos namadicus*, and *Hexaprotodon palaeindicus* recovered from the Belan, Mahanadi, Manjra, Godavari, Ghod and Krishna valleys, indicate a grassland ecosystem, with some forest cover, swamps and pools.

The study of Palaeolithic Culture in Peninsular India, which is the main thrust of this research, will be discussed in detail in the following chapters.

1.6. Brief outline on the study of lithic variability within the Palaeolithic period

During the last few decades, researchers have mainly concentrated on the explanation of the processes encompassing the material expression of various cultural and technological traits (*e.g.* Bar-Yosef 2005; Bordes and Bordes 1970; Jelinek 1994; Kuhn 1995; Mellars 1989). Especially in the field of Palaeolithic archaeology, the research trend is towards explanatory models on the various factors responsible for assemblage variability (*e.g.* Bisson 2001; Bordes and Bordes 1970; Dibble 1984, 1987, 1995; Jelinek 1994; Kuhn 1995; Hayden *et al.* 1996; Nelson 1991). The explanation of changes and the investigation of their background is one of the most important research issues and it should be continually underpinned by methodological and theoretical refinement. What is evident from this trend is that archaeologists try to explore the relationship between the static archaeological record and the dynamic response of the hominins to various external constraints (*e.g.*, Andrefsky 1994; Barton 1990; Kuhn 1995; Rolland and Dibble 1990).

Such a trend in the Palaeolithic research is very useful for explaining the nature of the dynamics involved, but leaves something to be desired as a goal for lithic studies. Lithic studies can be more appropriately carried out by focusing on investigating the connection between prehistoric technological impact on the behavior and practices of the individual manufacturer/user of lithic artifacts. It should be underscored that current research on lithic studies, especially on the technological aspects of lithic artifacts, has been focused on several factors that contribute to the assemblage variability. However, this research trend is substantially limiting otherwise intriguing and valuable issues. A drawback of these studies is that too much emphasis seems to be put on the explanation of relationship between the characteristics of the assemblage and their temporal/spatial significances with a limited scope. Furthermore, this trend is too rooted in past research traditions themselves constructed by the academic background of the major proponents of the different research area: *e.g.* the Bordesian approach to the interassemblage variability of European Lower and Middle Palaeolithic (Bordes 1961; Débenath and Dibble 1994); Movius' dichotomy of the Old World Lower Palaeolithic traditions (Movius 1944), and so on. If this research trend is "paradigmatic" (Clark 1991:

577- 9), then the struggle to shift away from it and to endorse alternatives must be preceded by the exploration of the diversity and multiplicity of the various hominin survival strategies.

Diversity can be understood in various ways and its implications can be interpreted in different contexts; but it should be made clear that this study focuses on the technological features of lithic assemblages, especially on the relationship between the varied constituents of lithic technological organization and the formation of the characteristics of the lithic assemblages.

Assemblages may vary according to the variety of tool forms (typological variability) or by the proportions of different types of tools present in different assemblages (assemblage composition) (Dibble 1987, citing Bordes 1950; 1953; 1961). Factors to consider in discussing assemblage variability include the following:

- Necessity/opportunity/expediency
- Resource availability and changes therein
- Social and demographic factors (stylistic norms; cultural repertory; modes of information storage; modes of information transfer; life span; population density)
- Technological constraints
- Curation strategies

All of the factors affecting variability in earlier technological stages (intentionality, style, curation strategies, material constraints, convention, function, and individual skill) were still operative.

Modern humans and their hominid ancestors relied on chipped stone technology for well over 2 million years and colonized more than 99% of the Earth's habitable landmass doing so. Yet we only have a handful of informal models derived from ethnographic observation, experiments, engineering, and "common sense" to explain variability in archaeological lithic assemblages.

The goal of this study is to begin to develop and test formal models of lithic technology for hunter-gatherers. This research is framed in terms of behavioral ecology wherein evolution by natural selection, played out within a given environment, is the ultimate causal determinant of human behavior. In particular, I

explore the impacts of forager mobility and raw material availability on technological variability in archaeological lithic assemblages.

1.7. Area of study

In order to systematically evaluate the factors contributing to inter- and intra-assemblages and morpho-technological variability as well as the role of raw material contributing to the lithic assemblage variabilities between and among the array of Palaeolithic sites in Peninsular India, I have selected three complexes of sites from Peninsular India they are as follows:

- Khyad, Benkanari and Lakhamapur in Malaprabha Valley from Kaladgi Basin (Bagalkot District, Badami Taluk, Karnataka),
- Shankaragatta from Shimoga Basin (Shimoga District, Bhadravati Taluk, Karnataka) and
- Jwalapuram in Jurreru Valley from Cuddapha Basin (Kurnool District, Banganapalle Taluk, Andhra Pradesh).

1.8. The Problem

My thesis seeks to expand our understanding of Palaeolithic technology in terms of lithic assemblage variability through the analysis of the three sites selected for my research work namely Khyad, Benkanari and Lakhamapur from Malaprabha Valley (Karnataka), Shankaragatta in Shimoga Basin (Karnataka) and Jwalapuram in Jurreru Valley (Andhra Pradesh). In this study the wider cultural historical background will be referred only briefly on a general level and the main emphasis will be on discussing more site-specific problems within the present study area.

Questions related to technology:

- The meager research situation in India is also mirrored by the available comparative archaeological and geological material, publications about the Stone Age of the selected area are rare and very general in their approach. This is especially true when it comes to the studies of lithic technology. The majority of published lithic data is typologically oriented, and most of it is relatively general and descriptive in character. Typology and the classification of artifacts were seen as a first step, a means to an end, rather than the end in itself. The absence of technologically oriented descriptions of stone tool production is a widespread problem in India. However shifting focus from typology to reduction sequences

is crucial if the three lithic assemblages (Lower, Middle and Upper Palaeolithic) are to be used to obtain and explore behavioural inferences. Technological analysis is concerned with the examination of the production of knapped-stone artifacts. The study of the attributes of waste products (debitage) and tools are the most important methods for the study of knapped-stone technology, backed up with replication studies are almost absent in India.

- In the nineteenth century, the study of prehistory was built on a sequence of stages in the progressive evolution of technology. But archeologists have rarely addressed questions about the pattern and context of innovations, the sort of questions that historians of technology ask about the invention of clocks, printing presses, and steam engines. Where and when did major technological innovations take place during the Paleolithic? Were these innovations isolated, seemingly random events, or did they appear in clusters? Did they represent primarily new inventions (radical or discontinuous innovations) or incremental improvements on existing technologies (continuous innovations)? Were technological innovations associated with changes in climate and the effects of these changes on landscape and biota? Given the state of research, renewed investigations in Peninsular India are needed to identify more secure depositional contexts and stratigraphic sequences, allowing researchers to better document technological changes and behavioural activities (Michale D. Petraglia *et al.*, 2003) through time. The gradual shift from Lower Palaeolithic by the Middle Palaeolithic and followed by Upper Palaeolithic has been regarded as unidirectional and gradual in other words *in situ* evolutionary model for technological changes from Lower Palaeolithic to Middle Palaeolithic and then by Upper Palaeolithic has not been studied and documented properly.
- The most important and fundamental question on prehistoric lithic research is the processes by which prehistoric flintknappers produced their implements? And why did they produce the forms they did? Whether the lithics obtained from archaeological record represent a intentional end product or do they represent the ongoing process breaking, resharpening or as a discarded objects.
- In India most of the lithic studies gave much important to typo-technological approach and some of them gave a new approach to the lithic studies by using metrical parameters in order to determining the size and shape or morphological aspect of the stone tools collected (especially Large Cutting Tools from Lower

Palaeolithic). These studies on stone tools did not take into consideration other important 'variables such as tool functions, resharpening, and physical properties of raw material.

- Furthermore, in most geographic areas there is significant variation in the proportions of large cutting tools and other tool types between assemblages. Variability in lithic assemblages has not been successfully explained or fully explored. In India most of the lithic studies gave much important to typo-technological approach and some of them gave a new approach to the lithic studies by using metrical parameters in order to determining the size and shape or morphological aspect of the stone tools collected (especially Large Cutting Tools from Lower Palaeolithic) in order to explain the variability observed. Whether the variability seen in the lithic assemblage is a product of difference in hominid cultural traditions and/or functional activities or is there a simpler explanation for variability such as raw material properties and tool reduction? Has not been studied.
- Traditionally the Stone Age lithic collections in Peninsular India have been associated to some wider spread industrial complex, making comparisons between sites situated hundreds of kilometers from each other and in a wide range of ecosystem. This might be unfruitful, instead the lithic technologies should be studied on a more localized level and then compared to each region in order to find an answer to the factors responsible for the variability within each assemblage from different regions.

Questions related to raw material that are of interest are:

- Hardly any work in India is done on certain aspects of raw material, including quantity, quality, accessibility, and size and shape which have long been known to influence archaeological lithic assemblages.
- Emphasis on raw material variability as a significant factor underlying Paleolithic assemblage variability in particular began relatively recently in other parts of the world, but there has been no such work done on the variability of raw material, and the possible effects that differential access to raw material might have on Palaeolithic assemblages have not been studied in India.

1.9. Research objectives and methodology:

The most important goal of this thesis is to systematically evaluate factors contributing to inter-and intra assemblage standardization and variation, using lithic assemblages from the sites selected from study. A detailed study of lithic assemblage from these three regions is likely to delineate the patterns of hominid behaviour during the Palaeolithic period. The objectives of my research has been subdivided into two major parts on which I am going to work they are as follows:

a. Raw Material

The role of raw material, in terms of availability, quality, size and procurement pattern contributing to the lithic assemblage variability between and among the array of Palaeolithic sites will be addressed in this thesis. The physical properties of various lithic materials and size strongly affect the manufacture and utility, this statement will be tested with the help of replicative experiments conducted by me. Another goals of the current research work is to explore some of the possible effects that differential access to raw material might have on Palaeolithic assemblages. The present study will also address how raw material variability and intensity of utilization influence other aspects of assemblage variability in the Palaeolithic assemblage from the selected three regions.

Diachronic industrial changes at a single site are usually not explained in terms of raw material variability because it is often assumed that local sources are constant. However there is the possibility that these sources do change significantly through time. This can be due either to changing climatic conditions affecting the exposure of local raw material sources will be addressed in this present research work.

Artefact clusters and their proximity to outcrops of rocks will be studied in this thesis. This will tell us about the hominids activities in terms of landuse pattern.

b. Technology

"Technology" means the various processes that contribute to the production of stone tools, including strategies of manipulation and sequencing, knapping equipment, and knowledge of raw materials and operative forces. A technological system describes the dynamic and open interrelations of the material and behavioral

components that serve to classify knowledge and techniques for the production of a specific technology. This definition of "technological systems" incorporates specific elements utilized by French cultural technologists (i.e., technological systems as a network of chaînes opératoires practiced by a group) (Lemonnier 1992; Roux 2003) as well as other researchers who employ a complex systems approach (i.e., open systems model and non-equilibrium) (Bentley and Maschner 2003; Van der Leeuw and Torrence 1989). The study of the attributes of waste products (debitage) and tools are the most important methods for the study of knapped-stone technology, backed up with experimental production. A very wide range of attributes may be used to characterize and compare assemblages to isolate (and interpret) differences across time and space in the production of stone tools.

1.10. Methodology

The research methodologies undertaken for this research work are as follows:

1. **Library work:**

Achievement of the aims outlined above required a large amount of published data to be referred. Library work involves collection of all available published literature on Palaeolithic period in the form of research article, monograph, excavation report, and published & unpublished Ph.D. thesis in India as well as from abroad. Published material relating to geology, chronology, palaeo-environment, palaeo-anthropology, hominid behaviour and lithic technology will be referred for

2. **Field survey:**

The first set of surveys will involve field-walking and planning a transect where the lithic scatter is more. For raw material characterization study a transect will be planned in order to recognize and mode of selection of raw material which was employed to manufacture stone tools. Already explored and excavated sites will be relocated on the site map. Field studies will concentrate on geoarchaeological aspects. Geological and geomorphic settings of these sites will be studied and this in turn will be helpful in reconstructing palaeo-landforms where the hominids stayed. Field survey will enable us to understand the land use pattern (like the distance between site and raw material source) during the prehistoric times.

3. **Map reading:**

Map reading will help in understanding the palaeo-landforms. In order to understand the man-land relationship during the past, map reading is an important procedure. This involves referring to geological map in order to locate the raw material sources, which had been exploited by the hominids in the present area of research.

4. **Artifact Form and Manufacturing Technological studies:**

This part of the methodology presents an account of the sampling and analytical procedures used to gather the data and descriptive characteristics derived from the extensive typological and technological analysis of the three regions lithic assemblage. The lithic assemblages from the three areas under consideration will be analyzed using Isaac's (1986) Method of Residual approach for determining the factors governing variability. Isaac's approach is a formal methodology to identify and evaluate source of variation that include raw material, economy of flaking, function, curation, and culture/style. In the first two steps of the Method of Residual, determine the mechanical and logistical constraints on raw material. The basic steps of the Method of Residual are outlined below: -

1. What are the expected flaking strategies—taking into account 'least effort flaking' of naturally occurring raw material?
2. What type of tool forms would be expected when one takes into account economy of flaking and transport; does this account for variation?

In the remaining steps, first function and maintenance are considered as sources of variation. After which all remaining variation is finally considered to be cultural/stylistic.

3. Does tool function and maintenance possibly influence the form of the artifact?
4. If all three factors above have been taken into account, then the residual variation in the form may be interpreted as stylistic influence on the tool or toolkit.

The methodology outlined below attempts to operationalize the first two steps of Method of Residual:

1. A geological transect was undertaken by me to identify the source. To obtain maximum amount of information about the raw materials shape and size a raw material characterization study was done. The parameters used for raw material characterization studies are:
   i. Wentworth scale
   ii. Roundness
   iii. Wadell's sphericity scale
   iv. Munsell's colour chart
2. The sampling strategy was to obtain data on a wide range of excavated and explored archaeological sites that were considered typological and morphological distinct and had different geological contexts. Stone tools were subdivided into technological and typological categories based on form, size, and shape. Individual artifacts of each region were categorized into one of 6 raw material types. Metrical and non-metrical attributes were recorded, including raw material, percentage of cortex present, length, breadth, thickness, weight, edge angle, scar count, and stepped scar count.

Artifact Form

Stone artifacts were categorized based on general technological attributes of conchoidal fracture. These classes are determined by the physics of stone fracture and based on lithic typo-technological terminology used by previous African Palaeolithic researchers (Isaac & Harris 1997; Kleindients 1962; Kleindients & Clark 1974; Leakey 1971; Toth 1982; M. P. Noll 2000).

Artifact forms were classed as:

1. *Cores* A core is the scarred nucleus resulting from the detachment of one or more flakes from a lump of source material. The core exhibit negative scars from detached flakes. The surface area of the core that received the blows necessary for detaching the flakes is referred to as the striking platform. Cores are further categorized based on the platform namely

i. **Single Platform-** Consists of Single Platform and Unidirectional Bipolar. Single Platform core- Single platform cores have single flaking platform from which flakes are removed.

   Unidirectional Bipolar- flaked unidirectionally with hammerstone on an anvil producing diagnostic platform at two opposed ends of the artifact.

ii. **Multiplatform-** Consists of Multiplatform, Multidirectional Bipolar. Multiplatform cores- has two or more flaking platforms. Multiplatform pieces have few flake scars and shape is often irregular and non-symmetrical. Multidirectional Bipolar- flaked multidirectionally with hammerstone on an anvil producing diagnostic platform at more than tow-opposed ends of the artifact.

iii. **Core fragment.**

2. *Flaked Pieces* Flaked pieces were further categorized based on morphological/ typological divisions of shape and dimensions, as well as initial form and direction(s) of retouch. Most of the flaked forms (pieces) can also be considered as cores rather than discrete types. The classification system used here is based on classification systems of earlier Africanist archaeologist (Kleindients 1962; Leakey 1971; Kleindients & Clark 1974; Toth 1982; Isaac & Harris 1997; and M. P. Noll 2000). The types of flaked pieces include:

i. **Unifacial pieces-** On a unifacial piece minimal flaking (<5 flake scars) in one direction (from the dorsal or ventral side). Shape is often irregular and non-symmetrical. Unifacial pieces differ from scraper and core scraper in having more acute edge angles.

ii. **Scrapers-** Scrapers have steep retouch along one or more edges. Scrapers are categorized based on the location and edges were the retouch has been done. They are as follows:

   a. Side Scrapers.
   b. End Scrapers.
   c. Double Side Scrapers.
   d. Double Side and End.
   e. Double Side and Double End.
   f. Convergent Scrapers.

iii. **Core scrapers-** Core scrapers are >10 cm in maximum dimension and have large, steep, unidirectional flake scars. These types are often manufactured on tabular piece, large thick flake or a split cobble.

iv. **Choppers-** Usually Choppers are made from rounded cobble that are flaked around a portion of their circumference. Flaking may be unidirectional or bidirectional, and the edge angle is usually more acute that that of a core scraper.

v. **Bifacial pieces-** Bifacial pieces are minimally retouched (<10 flake scars) in two directions from one platform. These differ from choppers in having an irregular and non-symmetrical shape. They are often produced on angular pieces or slabs.

vi. **Discoid-** Discoid have 50% of the circumferences is flaked, often bifacially.

vii. **Large cutting tool (LTC's) -** Large flaked unifacially or bifacially pieces. The primary form may be large flakes, tabular slabs, or from a flattened cobble. Handaxes, cleavers, knives, and picks are considered classes or sub-types of large cutting tools. Large cutting tools are frequently (but not necessarily) symmetrical in plan- and cross-section.

viii. **Polyhedrons-** Polyhedrons have at least three, often intersecting platforms.

ix. **Other and miscellaneous-** Pieces that do not fit into the above categories (e.g., burin, awls, borers and so on.)

3. **Battered and pitted stone:** Stones that exhibit use in battering and or pounding, including anvil, hammerstone.

4. **Detached pieces:** Complete flakes, broken flakes (longitudinal breakage and transverse breakage) and flake pieces that are detached from a core or a flaked piece during knapping.

i. *Complete flakes-* Flakes which have proximal (platform) and distal (end of artefact and they do not show any longitudinal or transverse brakage.

ii. *Broken flakes:* Flakes that is broken longitudinally or transversely. They should retain some parts of the flakes.

iii. Flake piece: These represent angular shatter or waste.

These detached pieces were broadly divided into various groups in order to reconstruct the technological modifications a stone underwent in between the time of raw material procurement and the discard of the artifact into the archaeological record. Technological observations derived from flake morphological analysis (like cortex percentage, flake initiation, platform width, platform thickness, platform surface, dorsal scar count, flake length, flake width, and flake thickness) was tested via an informal knapping program conducted by the author. The technological groups are as follows: (1) Early Reduction Flake (ERF), (2) Late Early Reduction Flake (LERF), (3) Late Reduction Flake (LRF) and (4) Bifacial Thinning Flake (BTF).

5. **Unmodified pieces:** Stones that are not flaked and do not display evidence of battering, grinding, abrasion, or pounding. These stones may have been transported to this sites by hominins (some call these stones as manuports)

Other variables

Stone artifacts were subjected to metrical and non-metrical attribute analysis based on general artifact form in order to quantify morphological variability. Core, flaked pieces, battered pieces, complete flakes and unmodified pieces were analyzed in detail. Broken flakes, flake pieces and core fragments were grouped by raw material type and by maximum size. Common metrical and non-metrical attribute made on individual artifacts were as follows: -

- Raw material
- Percentage of cortex
- Cortex type: - This will help us to understand the degree of weathering of the natural clasts and selection of the natural clasts for knapping. They are as follows: (1) Angular, (2) Sub-Angular, (3) Sub-Rounded, (4) Rounded, and (5) Indeterminate.
- Cortex location: - The presence of cortex are recorded as (1) Dorsal, (2) Platform, and (3) Both.
- Degree of patination: - Degree of Patination is recorded as (1) Absent, (2) Light, (3) Moderate, and (4) Heavy.
- Degree of edge rounding: - Is recorded as (1) Absent, (2) Light, (3) Moderate, and (4) Heavey.

- Colour of raw material: - Colour of raw material is recorded with the help of Munsell Colour Chart.
- Weight: Measurements were recorded to the nearest gram (gm).
- Maximum dimension: - Measurements were recorded in millimeters (mm) at the maximum dimension of the artifact.
- Maximum width: - Measurements were recorded in millimeters (mm) at the maximum width of the artifact.
- Length: - Measurements were recorded in mm.
- Thickness: - Measurements were recorded in mm.

Measures made on individual artifacts (core, flaked pieces, battered pieces, complete flakes and unmodified pieces) were as follows:

1) *Cores.* In addition to the common metrical and non-metrical attributes many other attributes were taken on individual artifacts they are as follows: scars >15mm, longest face, number of rotations, number of non-feather termination, base thickness, number of elongated parallel scars, platform preparation, platform surface, platform width, platform thickness, last platform angle, number of platform quadrants, measurements (like length, face length, width, and termination type) of four flake scars on the core and direction of flaking (e.g. bidirectional, unidirectional, multidirectional and radial) will be recorded. These variables were selected in order to measure the reduction sequence within the core. It is generally believed that the gradual reduction of cores will result in more flake scars and less cortex % that continued use of a platform will result in decreases in platform size, and that as more mass is struck from a core the size of the core and resulting flakes might also decrease. If cores are rotated during this process to create fresh platforms once old ones become damaged or unproductive, cores should begin to preserve sings of former sings of former flaking on the platform surfaces as well as indications of the existence of old platform.
2) *Flaked Pieces.* In addition to the common metrical and non-metrical attributes many other attributes were taken on individual artifacts they are as follows: (1) For retouched artifacts: Retouched length, length of margin, length of backing, amount of retouch, retouch angle and retouch thickness is measured at three different places on the specimen, index of invasiveness is measured in degrees as

0.5 and 1 at different place at the margin of individual specimen in order to measure the reduction based on diminishing flake weight, retouch diameter, retouch depth, retouch location, number of retouch segment and typology for retouched specimen. (2) For a notched artifact: number of notches, notch type (simple and complex), notch location, notch width and notch depth. (3) For a burin: number of burin spalls, number of platform, origin of burin blow, number of stepped scars, burin platform type and spall lengths and if these spall are stepped or not. (4) Large cutting tools were subjected to additional measures. (5) For choppers: initial form (flake, pebble, cobble, slab, blocky and indeterminate), profile form (straight, regular and irregular), total number of scars, total number of non-feather termination and typology for choppers.

3) *Battered and pitted stone.* Common metrical and non-metrical attributes are recorded.

4) *Complete flakes.* In addition to the common metrical and non-metrical attributes many other attributes were taken on individual artifacts. Metrical attributes like proximal width, medial width, distal width, bulb thickness, platform width, platform thickness and exterior platform angle. Non-metrical attributes like termination type (feather, hinge, step, outrepasse and crushed), Toth's flake type (cortex distribution), bending, platform surface (single conchoidal, dihedral, multi conchoidal, cortical, crushed and focalized) , platform preparation (overhang removal, faceting, both and grinding), dorsal scar count, dorsal scar pattern, number of unidirectional arrises, number of bidirectional arrises, number of radial arrises and edge damage were recorded.

5) *Broken flakes, flake pieces and core fragment.* These artifacts forms were grouped by raw material and maximum dimension. Proximal flakes had platform thickness, platform width, platform surface, platform preparation and exterior platform angle measured. According to the nature and place of the breakage, broken flakes are divided into two group's namely (1) longitudinal and (2) transverse brakeage. Flake pieces and core fragment were not measured individually.

6) *Unmodified pieces.* Common metrical and non-metrical attributes are recorded.

Description of metrical and non-metrical attributes:

Linear measurements of stone tool were taken using electronic digital calipers (accurate to 0.1mm), weights were measured by using pocket scale PS-200B for small artifacts (accurate to 0.1 gm) and Satrue-SWL-5 for big artifacts (accurate to 0.5gm). Edge angle were determined using a goniometer.

Additional attributes for shape/morphological measures of large cutting tools were taken according to the system developed by Roe (1964) and modified by Isaac (1977)

- L1 = Distance from the base of the LCT to the point of maximum width
- B1 = Width of the tip at 1/5 of length down from the tip (tip width).
- B2 = Width of the base at 1/5 of length up from the base (base width).
- Th1= Thickness of the tip at 1/5 of length down from the tip (tip thickness).
- Th2= Thickness of the base at 1/5 of length up from the base (base thickness).

The additional measurements taken for large cutting tools are then used to generate indices. They are as follows:-

- A pointed type will have an L1/L of <0.350.
- An Ovate type will have an L1/L of >0.350 but <0.550.
- A cleaver type will have an L1/L of >0.550.
- B1/B2 would assess the width of the tip relative to the width of the base.
- B/L would show us how wide the artifact is in relation to its length.
- Refinement index: T/B. Roe (1964)
- Refinement index: T1/L. Roe (1964)
- Shape Index: B/L. Roe (1964)
- Shape Index: B1/B2. Roe (1964)

Additional measurements for ascertaining the morphology of large cutting tools were taken they are as follows:-

Initial form

Initial form refers to the initial point form which the flaked piece was made. Initial form categories includes pebble, cobble, slab, blocky, flake, and indeterminate. Pebble, cobble, and slab were identified by the presence of cortex on the artifact. Flakes were identified by the presence of one or more attributes, including presence of platform, bulb of percussion, flake release surface, and ripples on the convex ventral surface.

Measurement of Invasiveness (in %).

This is a variable used on large cutting tools. Individual artifact has two sides (Side1 and Side2). Side1 was divided into two segments vertically namely Edge1 and Edge2, further these two edges were sub- divided into eight smaller segments horizontally each Edge having four divisions equally (namely Edge1of 1, Edge1of 2, Edge1of 3, and Edge1of 4 and Edge 2 had four subdivisions namely Edge2of 1, Edge2of 2, Edge2of 3, and Edge2of 4). Side 2 was divided in the same manner as we have seen above. The invasiveness was estimated in each of the above said subdivisions using discrete categories (<25%, 26-50, 51-75, and >76). This would tell us about the various reduction stages involved during axe manufacture. A high % of invasiveness would tell us that, minimum number of flakes has been removed from a particular specimen and this will in turn tell us about the different stages. (This will be supported by conducting an informal replicative studies)

Total number of flake scars observed on a large cutting tool

Scar count provides a quantitative measure of flaking intensity. Scar count on a large cutting tool was estimated using discrete categories (total number of flake scars <15mm, total number of flake scars 15-30mm, and total number of flake scars >30mm). Higher number of flake scars from the 1st categories indicates more intensive flaking of the large cutting tools and it also indicates that the specimen is in later stage of reduction. Higher number of flake scars from the 2nd categories indicates that the specimen is in the middle stage of reduction. Higher number of flake scars from the 3rd categories indicates that the specimen is in early stage of reduction.

Total number of non-feather termination

Non-feather termination count measures the total number of abrupt termination scars (e.g. steeped and hinged) on a large cutting tools. Non-feather termination flake scar provides an indication of the difficulty in flaking. A high frequency of non-feather termination scars relative to the scar count indicates difficulties in flaking that particular raw material and the errors of the kanpper.

Cortical surface

Percentage of cortex remaining on flaked pieces was estimated in percent (%) and was recorded as 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% respectively. This category can provide a qualitative measure of the intensity of flaking.

Tip shape

This is variable used here as a proxy for shape variation between bifaces and cleavers. It is applied to any LCT irrespective of its 'typological' interpretation. This section is designed to explore the variability present within 'established' categories of artifacts. The tip is here taken to be the upper third of the artifact. The shapes are as follows: (1) Markedly convergent: Can have an acute or rounded tip (but must be visibly narrowing). Tip must be long and clearly tapering. (2) Markedly convergent but with a squared off tip. The tip is at roughly right angles to the long axis of the artefact. (3) Same as the above one (i.e., (2)) but with a clearly oblique shaped tip at an angle to the long axis of the artefact. (4) Markedly convergent with a generalized tip. 'Generalized' means that the tip doesn't fit into categories (1) – (3). (5) A right angled and broad tip on an artefact with divergent or parallel/sub-parallel sides at the cutting end of the tool. (6) Same as in (5), but with a wide tip at a markedly oblique angle to the long axis of the tool. (7) Wide with a very convex tip and without any break in the convexity.

Profile form

A profile form refers to the form of a flaked piece in a profile. Profile form categories include straight, regular and irregular.

Cross section

This attribute is an indicative of the shape of flaked piece and the categories are biconvex, lenticular, circular, high back, low back, triangle, sub-triangle, trapezoid, rhomboid, parallelogram, irregular, and polygon

Typology

Typology is one of the basic procedures adopted towards the archaeological record. Previously classification of archaeological assemblages into various typological groups was considered as an end in itself. Typology is instrumental in explanation of things as it provides us with the basic building blocks with which one can reconstruct the different aspects of a culture. Typology allows us to identify the differences and similarities with the material we have in hand. Archaeological specimens can take on a more meaningful place in an assemblage once a type is assigned. The subjective judgments associated with the assignment of types can be limited through the study of morphological attributes. Morphological typologies provide a comprehensive framework within which the entire range of implements found in assemblages can be inventoried. Typology and the classification of artifacts were seen as a first step, a means to an end, rather than the end in itself. Typology is the systematic organization of artifacts into types on the basis of shared attributes. Each assemblage was typologically coded using the typology developed by Maxine R. Kleindienst (1962) and Bordes (1961, 1968)

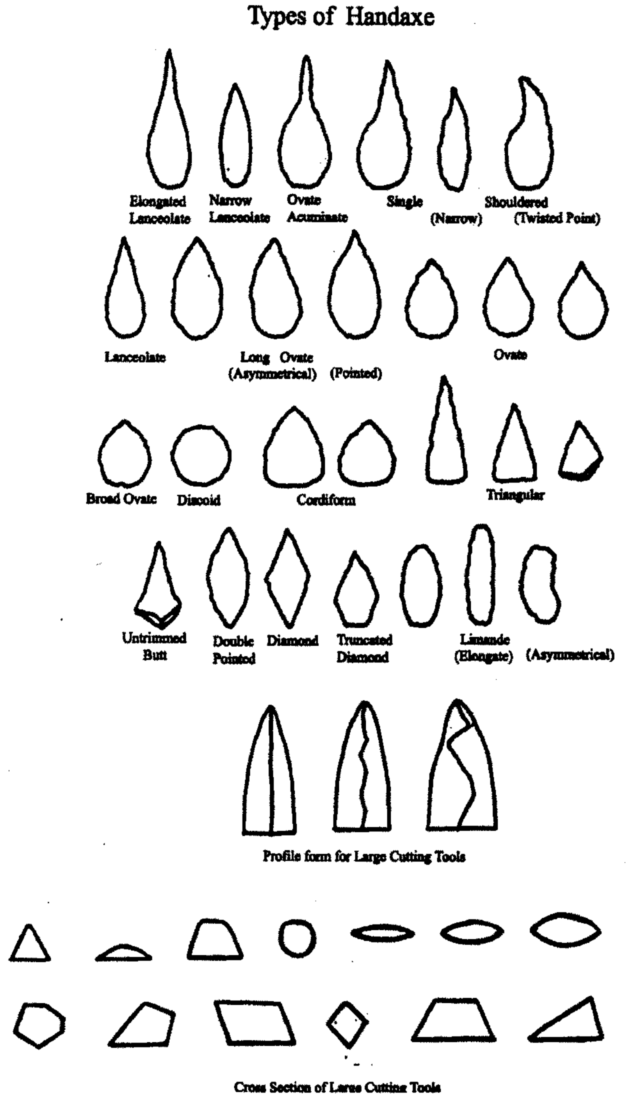


Figure 1.1 Types of Large Cutting Tool

Exterior platform angle (EPA). This variable measures the exterior platform angle of the complete flakes. Only one measure was taken on each specimen. Higher exterior platform will result in thicker and heavier flakes (early reduction flakes) and low platform will result in thinner and slender flakes (later stage of reduction flakes)

Platform width and platform thickness. These attributes will give us a picture on the reduction stage and how these attributes affect the morphology of a flake and core.

Platform preparation

This attribute will give us the information on the preparation of platform (overhang removal / faceted / grinding) before the removal of flakes from the core.

Dorsal scar count

This will give us a picture on the reduction stages. Increase in the dorsal scar count on a flake or a tool tell us that the flake has been removed in the later stage of reduction and decrease in the dorsal scar count tell us that it has been removed in the early stage of reduction.

Dorsal flake scar pattern

A specialized attribute for assessing the direction and the position of flake scar detachments on complete flakes is the dorsal scar pattern. Dorsal flake scar categories include form proximal, from left, from right, from distal, bidirectional, weakly radial, strongly radial, and crested. Dorsal scar pattern indicate the type of flaked the type of flaked piece from which a flake was detached (e.g. strongly radial scar pattern are often associated with discoidal or centripetal cores.

Flake type and termination type

These attributes will give us the information on the technique of knapping and it will tell us about their knapping skills.

In the period spanning the 1940s to 1970s scrapers were typically classified and named according to the location of retouch (e.g. side, end, side and end, double side and end etc), the nature of retouch (e.g. nosed, notched, denticulate), assumed function (e.g. knives, drills, pierces, adzes, choppers, planes, and scrapers), the curvature of the retouched portion (e.g. straight, round, convex, concave) overall shape and size (thumbnail, horsehoof, flat) and the steepness of the edge (e.g. low angled, steep edged) Combinations of these attributes and names were also employed at various times, usually in unsystematic ways, and often ending in large and confusing taxonomies (Clarkson, 2005). In order to get quantitative and qualitative information on retouched artifact these variables were adopted from Kuhn (1990) and developed by Clarkson (2002) this method has been adopted by present author, they are as follows:

Measurement of Invasiveness of a retouched artifact made from a complete flake, broken flake, and flake piece.

The measurement of invasiveness of a retouched artifact which allows fast and accurate calculation of flake scar coverage for both (dorsal and ventral) surfaces of an artifact. An artifact is first theoretically sub-divided into eight analytical segments on both its dorsal and ventral surfaces (Figure-1.2), giving a total of 16 segments to an artifact. For each segments a score was given as 0.5 and 1. To obtain the index of invasiveness total number of segments i.e., 16 segments was divided by the total score total score obtained. Further these sub-divisions are made such that each segment represents one-fifth (20%) of the total length of the artifact. The artifact's surface is then further divided into two zones for each segment, an outer zone and an inner zone (Figure-1.2). For the inner six segments (segments '2–7' and '10–15'), invasiveness zones are partitioned at the halfway point between the middle and the lateral margin of the artifact. For the proximal and distal segments (segments '1', '8', '9' and '16'), the marginal/invasive boundary is located halfway between the distal or proximal margin of the flake and the outer edge of the inner six segments.

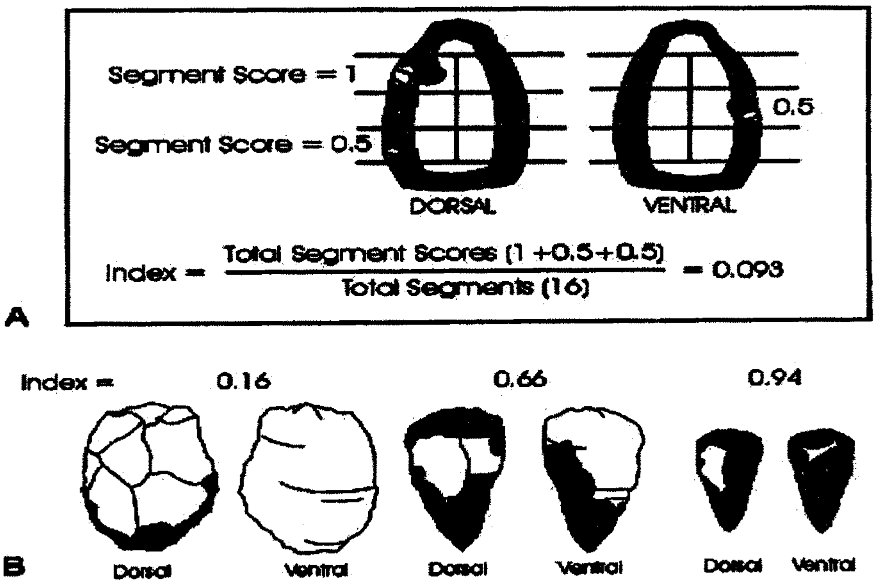


Figure 1.2. The index of invasiveness. A: Measurement procedures, B: examples of index results at different stages of reduction. (adopted from Clarkson 2002)

GIUR (Geometric Index of reduction on a unifacially retouched flake)

Kuhn (1990) developed a specialized system of estimating the amount of reduction on marginally and unifacially retouched flakes. The index calculates the extent of retouch by the relative "height" (ventral dorsal) of retouch scars. Kuhn presented two different methods for calculating what he named the geometric index of reduction. The first method quantifies edge attrition by dividing the height of retouch scars above the ventral face (t) by the maximum thickness of the flake (T). Both measurements were taken at right angles to the ventral surface and at the same point on the retouched edge (Figure-1.3). Both t and T is measured directly using calipers.

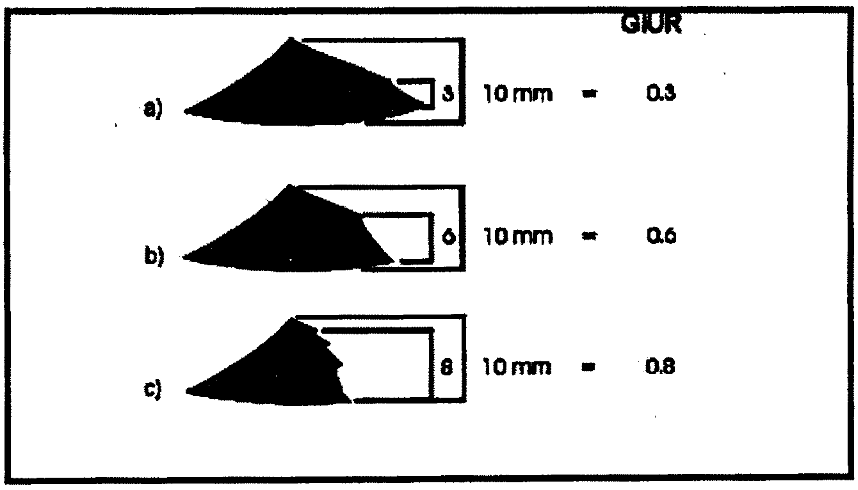


Figure 1.3. Measurement procedure of the geometric index of unifacial reduction (adopted from Kuhn 1990)

Edge curvature

Edge curvature is a specialized attribute for assessing the observed changes in implement morphology. Edge curvature is obtained from calculating the retouch diameter divided by retouch depth. As retouch perimeter is observed to increase with retouch intensity, it might also be expected that the retouched edge would become increasingly curved as more of the perimeter is worked. Edge curvature is here calculated by dividing the depth of retouch by its diameter (Figure-1.4). Using this technique, concave edges give a negative result while convex edges give a positive one. It is indicates that edge curvature, which begins as a slightly concave edge, becomes highly convex as the Kuhn Index increases.

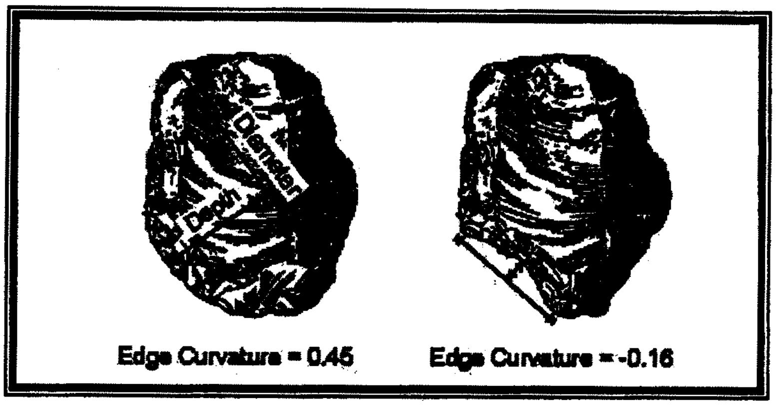


Figure 1.4. Measurement procedures of curvature of the retouched edge in order to describe flake shape (Clarkson 2002; Hiscock and Attenbrow 2002, 2003).

5. Replication study:

Different varieties of raw material utilized by the hominid from these three regions will be subjected to replication experiments to be able to demonstrate the technological stages developed during the Palaeolithic. Lithic replication studies encompass a broad field of experimental approaches to stone tool analysis and provide information on several levels. Extensive knapping replication studies continue to emphasize the usefulness of the experimental approach in lithic analysis and interpretation (e.g. Bordes and Crabtree 1969; Bradbury and Carr 1999; Callahan 1985; Crabtree 1966, 1972; Patterson 1982; Pelegrin 1981; Pétrequin et al. 1998; Stafford 2003; Whittaker 1994). Replication studies are conducted in order to understand the mechanisms of stone fracture and how these mechanisms produce lithic artifact assemblages. It could also show the extent to which variations in the raw material (and thus in the method of extraction) would affect the ways in which it had been used. Replication studies help us to distinguish between the form of a flaked stone tool and the means by which that particular form was realized (Edmonds 1990). I will use the replication study as a means to arrive at their specific end products. Results of these experiments are compared technologically with the prehistoric assemblages from these three regions.

1.11. The structure of the study is as follows

The **Chapter I** gives an overview on the Palaeolithic technology and human evolution of the world. The evolutionary history of stone tools and the terminology used in Palaeolithic period of the world and in India will be discussed. A brief outline on the study of lithic variability within the different phases of Palaeolithic period will be discussed in this chapter. This chapter outlined objectives and

methods used in this study. These objectives and methods are determined to reveal the variability observed in the lithic assemblage and whether this variability is due the technological aspects or raw material aspect. **Chapter II** reviews and summarizes the theoretical frameworks of research on the Palaeolithic assemblage variability of Peninsualr India. This chapter will provide a description of the geological context from which these tools are found, makers of the tools, the techniques involved in manufacturing the stone tools and the dates of these sites. As a whole this chapter will discusses about the various aspects which are connected with the Peninsular Palaeolithic form Lower Palaeolithic (Middle Pleistocene) to Upper Palaeolithic (Late Pleistocene). **Chapter III** will provide an overview on the technological and raw material study in Peninsular India. With respect to the raw material, different types of raw material exploited through time will be discussed and technological issues like techniques employed, lithic reduction sequence and if there is any research on the debitage analysis made on Peninsualr Palaeolithic will be discussed. Chapter I, II and III are general in nature, these chapters' gives an outline of Palaeolithic in India with more emphasis given on Peninsular Palaeolithic. More site specific and problem oriented issues will be addressed in the coming chapters. **Chapter IV**, V and **VI** are devoted to presenting and interpreting data from each component and addressing research questions presented above. In order to address the research question, I have divided these three chapters into various subdivisions which are discussed below. In Chapter IV, V and VI provides a site description (i.e., location of site, Basin and local geology, lithistratigraphy and palaeo-environment reconstruction) and the history of archaeological research of all the three region under study, namely, Khyad, Benkanari and Lakhamapur in Malaprabha Valley from Kaladgi Basin (Bagalkot District, Badami Taluk, Karnataka), Shankaragatta from Shimoga Basin (Shimoga District, Bhadravati Taluk, Karnataka) and Jwalapuram in Jurreru Valley from Cuddapha Basin (Kurnool District, Banganapalle Taluk, Andhra Pradesh). From these regions the description of raw material (location and sourcing of raw material, extraction of raw material, site-to-source distance and raw material diversity: richness and evenness measures) and raw material characterization study (planning a geological transect and then numbering the natural clast which are collected, measuring and weighting the natural clast, grain size analysis, sphreicity and roundness of natural clast and colour of clast) from the sites will be discussed in these chapters. The next subdivision from

these three chapters will deal with the lithic analysis separately from each region. Lithic analysis involves classification of lithic assemblages into various groups with the help of typological classification and with morphological and morphometric analysis of lithic assemblage when supplemented with statistical methods. Another subdivision of these chapter is based on the technological aspects (like reduction sequence and debitage analysis), where the manufacture of the lithics from these region will be discussed starting from the raw material selection to the end product. Then the next part of these chapters will be on the comparative aspects like comparison between the raw material type to the technological and morphological aspects of the lithic assemblage. Whether the raw material shape and size, and grain size had any influence on the lithic assemblage variability will be discussed. Last part of these chapters will be on the replication studies and at the end discussion. In this part the raw materials collected from each site will be subjected to informal knapping experiments, in order to delineate the technological and functional aspects lithic studies. **Chapter VII** will be on the inter site comparison of lithic assemblage in-between regions. With all these analysis done I will be in a position to talk about the behavioural pattern of the hominids from these three regions. **Chapter VIII** will be a synthesis based on the research presented in the previous parts of this thesis. Variables such as tool functions, effect of raw material, and the reuse/resharpening of the artifacts account for the variability observed in the lithic assemblage from these three regions. Results from the previous chapters will allow an assessment of the behavioral and conceptual capabilities of hominids form the Middle Pleistocene to the Late Pleistocene of these three regions. A glossary of terms and descriptive and metrical data on the sites and artifact assemblages are provided in appendices.

Chapter-2

Investigating Palaeolithic Assemblage variability in Peninsular Palaeolithic: Background and Theoretical Frame work

2.1. An overview on Palaeolithic studies in India

The archaeological records for the Palaeolithic period in India are very rich. The earliest human colonization of India is represented largely by the abundance of stone tool assemblages. The search for Palaeolithic remains have began in India with the discovery of quartzite handaxe from ferruginous lateritic gravel in Pallavaram (R. B. Foote 1866), a military cantonment south- west of Madras, South India by Robert Bruce Foote on 30th May 1863 (F. R. Allchin 1961; Roy 1953, 1961; D. K. Chakrabarti 1979, 1981; R. Korisettar 2000; R. S. Pappu 2001). Robert Bruce Foote was a geologist cum archaeologist. He took keen interest in two fields viz., prehistoric archaeology and Quaternary geology and carried out investigations in both the fields for more than thirty years in southern and western India. Four months later after the discovery of first handaxe from Pallavaram (North Madras) Robert Bruce Foote accompanied a colleague, William King, to the Kortalayar valley to investigate the eroding cliffs in the nullah of Attirampakkam. William King picked up two stone implements from the stream -bed on 28th September 1863(K. A. R. Kennedy 2000). A number of geologists of the Geological Survey of India and a few civil servants have reported Palaeolithic artifacts from a number of river valleys in India. A. B. Wynne (1865) picked up an agate flake from Paithan-on-Godavari along with animal fossils. Palaeolithic tools were reported at Banda and Singrauli Basin, Mirzapur district, Uttar Pradesh by Rivett-Carnac (1884) and Cockburn (1888). In 1873, C. Hackett picked up a handaxe made of quartzite together with animal fossils from the river Narmada at Bhutra in Madhya Pradesh (Medlicott 1873). In 1876 Ball reported few Palaeolithic tools from Dhenekal, Angul, Talcher, Sambalpur areas in Orissa and Bankura in West Bengal (Ball 1865, 1880). Again in 1876 Ball, who reported few Palaeolithic tools from Bihar and Chota Nagpur plateau (1870), made some discoveries at places like Dhenekal, Angul, Talcher and Sambalpur in Orissa and Bankura at West Bengal. After him few people like Beeching (1868) and Anderson (1917), collected some of the stone tools (palaeolithic) from the same places where Ball already discovered. North central India was surveyed by A. C. L. Carlyle, he discovered the Lower Palaeolithic artifacts provenance to Marfa in Uttar Pradesh and noted this as a workshop site it remained unrecognized till know (Ravi Korisettar 2000). Not much attention was given to the Palaeolithic of north India in the last quarter of the nineteenth century (Korisettar 1995).

During the middle of 19th century, two major international expeditions were launched in India by (i) L. A. Cammiade and M. C. Burkitt (1930) in collaboration with F. J. Richards, and (ii) De Terra and Paterson (1939) in collaboration with Teilhard de Chardin. Cammiade and Burkitt carried out investigations in Kurnool region of Andhra Pradesh. Based on the typo-technological aspects they divided the artifacts into four cultural stages, viz., Series I, II, III, and IV and observed similarities between southeast Indian sequence and the African ones developing under similar climatic cycles (Burkitt et al. 1932). Yale-Cambridge expedition under the leadership of de Terra (de Terra and Paterson 1939) undertook exploration in the glacial tracts of Kashmir Valley, the adjacent pre-glacial region of Potwar plateau, the Narmada valley in Central India and around Madras along east coast. This expedition recognized a four-fold glacial succession in the Kashmir valley, parallel to that represented in the Alpine sequence in Europe. This sequence worked out in Kashmir valley was correlated with terrace sequence observed in the river Soan in the Potwar Plateau. Stone tools were recovered from these terraces in the Soan valley. This expedition studied the Narmada valley between Hoshangabad and Narsinghpur in Madhya Pradesh. The alluvium from this place yielded a sequence of lithic industries of Abbevillian and Acheulain characters with a large number of Middle Pleistocene mammalian fossils. This expedition also studied the Kortalayar valley in Tamil Nadu. Stratigraphy worked on Kortalayar and Narmada valley was comparable in terms of cultural and sedimentary succession. Paterson identified a core-chopper industry (Soan Culture) restricted to north -west India and a bifaces industry (Madrasian) restricted to the Peninsular India. The Soan sequence was sub divided into five groups, which was developing from Pre Soan to Evolved Soan. Patterson considered Soan culture to be indigenous and the Madrasian as exotic originating from Africa, and the Narmada valley was the possible place of fusion gradually terminates Soanian Culture (de Terra and Paterson 1939; Krishnaswami 1947, 1953). De Terra and Patterson (1939) demonstrated the evolution of Lower Palaeolithic technology in an evolutionary development scheme of Early Soanian and Acheulian. Many archaeologists have found it difficult to accept the co-existence of two distinct technological traditions in close proximity without any influence on each other (Misra 1989). On the east coast Richards et al. (1932) made a detailed survey of the region around Manjankarani on the Kortalayar valley, north-east of Madras, and at Kannapuram on the river Godavari, Andhra Pradesh (Ravi

Korisettar 2000). On the west coast, K. R. U. Todd (1939) discovered a stratigraphic sequence near Bombay in Kandivali-Borivali region, which yielded lithic industries ranging from Lower Palaeolithic to Mesolithic. N. K. Bose and Sen (1948) undertook investigations in the Mayurbhanj region of Orissa. H. D. Sankalia (1946) carried out investigations in the Sabarmati, Mahi, Karjan and other river valleys situated in Northern Gujarat, an interdisciplinary programme. H. D. Sankalia organized planned explorations and teamed up with his students and began the survey the Deccan rivers such as Narmada, Godavari and Malaprabha along with on going Gujarat expeditions, which were productive (Sankalia 1942, 1943, 1945, 1946). These studies brought to light the evidence of lithic industries showing the Abbevillio-Acheulian characters.

During the Post-Independent phase in Lower Palaeolithic studies a multidisciplinary aspects were addressed by many scholars from India. During this period many dissertations with a multidisciplinary approach were produced under the supervision of H. D. Sankalia, and more than 40% of the dissertation were from the Peninsular India, from this few are listed below (Korisettar 2000):

Dissertation related to Peninsular India:

- R. V. Joshi's work on *Pleistocene Studies in the Malaprabha Basin: Prehistory and Geoarchaeology*, submitted in 1953. This thesis has published in the form of a book and is directly related to my area of research.
- N. Isaac's work on *Stone Age Cultures of Kurnool (Andhra Pradesh)* submitted in 1960. In this thesis he firmly established the presence of Upper Palaeolithic phase in India.
- M. L. K. Murty's work on *Stone Age Cultures of Chittoor District* (*Andhra Pradesh*) (1966)
- S. N. Rao's dissertation was on *Stone Age Cultures of Nalgonda District* (*Andhra Pradesh*) (1966).
- K. Thimma Reddy's dissertation was on Prehistory of Cuddappah (*Andhra Pradesh*) (1968).
- K. Paddayya's dissertation was on *Pre-and Proto-historic Investigation in Shorapur Doab* (1968).
- R. S. Pappu's work was on *Pleistocene Studies in the Upper Krishna Basin* (1974)

From other parts of India:

- Mohapatra's dissertation was on *The Stone Age Cultures of Orissa* (1960).
- V. N. Misra's work was on *Stone Age Cultures of Rajputana* (1961) region.
- N. Ahmad's dissertation was on *Stone Age Cultures of Upper Son Valley* (1966).
- S.G. Supekar's thesis was on *Pleistocene Stratigraphy and Prehistoric Archaeology of the Central Narmada Basin* (1968).
- S. Guzder's work was on *Quaternary Environments and Stone Age Cultures of the Konkan, Coastal Maharashtra* (1975).
- S. Chakrabarti's dissertation was on *The Prehistory of Bhavnagar District, Saurastra, Gujarat State* (1978).
- N. Armand's thesis was on *Excavations at Durkadi: a Pre-Acheulian Occupational Site on the Ancient Banks of the Narmada River, W. Nimar District, Central India* 1980).

Regional investigations in Peninsular India

The Karnataka Plateau:

Since the discovery of stone artifacts in the 19th century by Robert Bruce Foote, the Malaprabha Basin has been known as a source for Pleistocene archaeological sites. The most comprehensive archaeological investigations in the Malaprabha Basin were carried out in the mid-twentieth century by R.V. Joshi, described in the landmark publication, '*Pleistocene Studies in the Malaprabha Basin*', published jointly by the Deccan College Research Institute and Karnatak University (Joshi 1955; R.S. Pappu 1974; Pappu and Deo 1995). Later on Pappu and Deo (1994) carried out a morphometric analysis of the landforms of the Ghataprabha Valley in the northern parts of the Kaladgi Basin, their Quaternary stratigraphy corresponded with the upland rivers of the Deccan. Recent field investigations in the Kaladgi Basin have revealed that the Lower Palaeolithic yielding gravel bodies along the middle course of the Malaprabha and Ghataprabha (including Anagwadi and Kovalli) are a series of coalescent alluvial fans. Excavation in Anagwadi, a Lower Palaeolithic context did not however, help in identifying the primary context of the sites, despite the fact the artifacts associated with the gravel conglomerate did not reveal attrition of their edges. Major contribution of Pappu and Deo (1995) being the documentation of Palaeolithic sites away from the channeled water courses.

The survey of the Malaprabha River by Ravi Korisettar and Michael Petraglia (1993) resulted in the discovery of 20 Paleolithic sites and collection of over 900 implements. Joshi's research was pioneering with respect to the attention paid to geological, sedimentary and climatological features in the Basin. It was observed in the field work conducted by Ravi Korisettar and Michael Petraglia (1993), which an extensive calcrete surface developed over the older laterite surface followed by the Late Quaternary alluvial sequence. The artifact bearing conglomerates exposed in the bed of the Malaprabha (Kaladgi Basin, north Karnataka) can be traced away from the channels up into the piedmont region away from the river. These represent former alluvial fan systems originating from the Kaladgi ridges upon which the Late Quaternary alluvial deposits are superimposed in part burying the cultural material. The material is preserved across palaeolandscapes, Acheulian occupation post-dates the fan formation. The Acheulian sites do not correspond to the present drainage network, as supported by artifact size, material distributions, and the low level of rounded edges on artifacts. This seems to be the case with the majority of Acheulian sites in peninsular India. Artifact scatters away from the reach of pediment alluviation remained exposed on the surface and suffered in situ weathering. Whereas those artifacts buried under alluvium are unweathered but show wearing on the surface exposed to sub-aerial processes. It is also observed that both Lower and Middle Palaeolithic artifact distributions on the pediment surfaces are associated with ponds and lacustral clays and fine grained silts which were deposited by the now extinct water courses and that hominid activity loci were not related to channel networks as seen at present (see also Korisettar 1995).

The Hunsgi-Baichbal Valley

Stone Age research in the Hunsgi-Baichbal Valleys has been conducted since 1974 (Paddayya 1977a, 1977b, 1979, 1982a, 1985a, 1987b, 1987c, 1989, 1991). These prolonged investigations have brought to light a wealth of data pertaining to the Lower, Middle and Upper Paleolithic of the region. Based upon seven uranium-series dates, the Acheulian localities have been dated from 150,000 B.P. to a minimum of 350,000 years B.P. (Szabo et al. 1990). Based upon currently accepted hominid chronologies this occupation may belong to an advanced form of Homo erectus or early representatives of Homo sapiens. Surveys in the Hunsgi-Baichbal

Valleys by Paddayya have found localities away from major river valleys for reconstructing the settlement of Stone Age cultures (Paddayya 1978, 1982). This was in contrast to the then dominant research paradigm in Indian Stone Age research which concentrated on the construction of regional culture-sequences based on the study of secondary localities such as those associated with riverine deposits. Investigations in the Hunsgi Valley brought to light about 60 localities belonging to the Acheulian, and in the Baichbal Valley, another 50 Acheulian sites were identified (Paddayya 1982).

Recently, Paddayya and Petraglia (1993) have assessed the Hunsgi and Baichbal sites in terms of the processes which may have occurred in fluvial, colluvial, deflationary environments. Of the 110 Acheulian sites in the Hunsgi and Baichbal Valleys, assemblages from 7 surface and excavated sites were studied in detail. In an attempt to assess the cultural and natural formation of the sites, a set of artifact variables were examined (e.g., typo-technological information, morphological data, artifact size distributions, artifact rounding. patination, and weathering) (Paddayya and Petraglia 1993).

The Kortallayar Valley

Until the 1990s de Terra and Paterson's work on the classic sites of the Kortallayar Valley in the Madras region had not been reviewed, like those of the Potwar and the Narmada regions. Our knowledge of the terrace sequence as well as the cultural sequence was limited to the framework established by the Yale-Cambridge expedition (de Terra and Paterson 1939). Though Palaeolithic studies, including geologists and archaeologists, continued to be made in the 1960s they did not break any new ground. K.D. Banerjee carried out several seasons of excavation in this area and established the existence of river terraces at elevations of 73 m, 45 m, and 17 m above mean sea level (IAR 1962-63 to 1966-67). Though a detailed report was never published, brief comments on the Middle Acheulian character of the Lower Palaeolithic industry were made in the absence of stratigraphic development. However, it is not clear whether base level changes and corresponding sea levels were taken into account while identifying terraces at various elevations. Jayaswal (1978) in addition to making a fresh collection of stone tools from Vadamadurai and Gudiayam made a sytematic study of the collections made by the ASI and herself and the results have been included in her study of prepared core

techonology (Jayaswal 1978). Lower Palaeolithic industry of Chengleputu region was studied by A. Swamy, who had submitted a dissertation to the University of Madras (Swamy 1976) on the same aspect. S. Pappu (1966) provides a brief history of Lower Palaeolithic research in the Kortallayar Basin.

In recent decades Shanthi Pappu initiated an integrated study of cultural and natural site formation processes in the Kortallayar Valley under the supervison of K. Paddayya (S. Pappu 1996). During this study by S. Pappu (1989, 1996), she adopted the new perspectives and field techniques to arrive at a holistic picture of the Pleistocene man-land relationships in the Kortallayar Valley. This account of the Pleistocene stratigraphy, geomorphology, a tapohonomical study of the Palaeolithic sites and the archaeological patterns within them as well as a technological study of the lithic assemblages enabled to provide with a behavioural model of hominins.

Apart from this in 2003 and 2004, archaeological investigations, as part of the Kumool District Archaeological Project (KDAP), were earned out at the site of Jwalapuram in the Jurreru valley (figure 5.1) by Karnatak University and the University of Cambridge, under the direction of Prof. R. Korisettar and Dr. M. Petraglia. Extensive deposits of Toba ash are preserved in the Jurreru valley, sometimes reaching ~2.5 metres in thickness. Palaeolithic artifacts that pre-date and post-date the ash have been recovered during excavations in the valley, providing an excellent source of information regarding the eruption's impact on hominin populations in the region.

The western coastal region

Sporadic occurrence of Lower Palaeolithic artifacts was reported from the north Konkan. Evidence for Lower Palaeolithic occupation on the West Coast has continued to elude archaeologists. From Goa a solitary pebble chopper from Shigao on the Dudhsagar River was found as early as the 1960s. However, it was not sufficient evidence to establish the Lower Palaeolithic occupation in this region. Further survey in the 1980s did not produce any convincing Acheulian artifacts, but for a few pebble tools from the Mandvi Basin. It is only recently in the 1990s, undisputed Lower Palaeolithic artifacts were reported from the Dudhsagar Valley at the foot of the Western Ghats (Goudeller & Korisettar 1993). Coastal north Karnataka is yet to be surveyed. A quartz chopper assemblage is also reported from Kerala and a couple of bifaces have been found in coastal Karnataka.

3.2. Lower Palaeolithic industrial complex

The earliest evidence of human beings in India known to us at present belongs to the Lower Palaeolithic culture through their stone tools. The Lower Palaeolithic culture in India comprises two distinct traditions, viz., the Soan or Sohan, represented by pebble tools, also known as chopper-chopping tool tradition, and Madrasian or biface or handaxe-cleaver tool tradition. The region lying to the north of the Narmada has mainly yielded lithic assemblages dominated by the chopper-chopping tools while peninsular region, i.e., south of the Vindhyas, has brought forth industries of the handaxe-cleaver tradition. During this stage (Lower Palaeolithic), two cultures or technological traditions of stone tools flourished side by side. The Soanian Culture was considered as indegenous and the Madrasian as exotic coming from Africa.

It may be recalled that the handaxe is common to European and African Palaeolithic cultures. Pebble tools, such as the choppers, and core tools, such as the cleavers, are rare in Europe, but present in both Africa and India in large quantities. In Central Asia and China, handaxes have been rarely reported but choppers and chopping tools occur in abundance in India, at this juncture, it is significant to note that handaxes and pebble tools occur together not only in the Potwar region of Pakistan but also in the north-west sub-Himalayan region of India, near Chandigarh in particular, including Markanda Valley, south of Shimla. Such a manifestation can also be found in many other sites in the peninsular India, including the Vindhyas, near Mirzapur. Thus, it is no more tenable to hold the theory that northern India was the homeland of chopper-chopping tradition of the Pebble tools and the south India of handaxe-cleaver tradition of Core tools, tools of both the traditions are found together at many sites in northern India as well as southern India even though pebble tools dominate the north Indian sites and core tools dominate the south Indian sites. Peninsular Palaeolithic is dominated by handaxe industry of Acheulian culture.

Acheulian Culture

The Acheulian Culture is named after the site of Saint Acheul in France. It is a 'Core Tool' Culture in which handaxes and cleavers made on rough stones or thick flakes predominate. However, this culture has also flake-tools, generally scrapers. The Acheulian industry in India is characterized by bifacially flaked artifacts like

handaxes and cleavers, along with bifacial and unifacial choppers, denticulates, scrapers, spheroids, and picks amongst other tools. Some times these handaxes were unifacially worked. Tools of this culture are found mostly in south India, in its river basins but these are also found at sites slightly away from the rivers, although generally near them.

As the handaxes were first found near Madras (the old name of Chennai) and this industry was found centered around the Korthalayar river basin, near Chennai, at sites Attirampakkam and Vadamadurai, the Yale-Cambridge Expedition suggested that the Early Stone Age industries of south India be termed as 'Madrasian' in contrast to the 'Soanian' of north India.

The first effective migration of Lower Palaeolithic people in India was accomplished by the makers of the Acheulian culture. The remains of this culture have been found from the Siwalik Hills in the north to areas near and beyond Chennai (Madras) and many other sites in all the States of south India. The Acheulian industry is much more wide spread all over Indian than the Soanian tradition.

Tool Types from Lower Palaeolithic

The Sohanian is a pebble (water-worn stones) tool industry. These tools are generally quite big and massive, but smaller ones are also found, and are made by flaking suitable pebbles. These pebbles are generally flattish, oval, elongated, oval or circular in shape. These are generally of quartzite stone. Chopper and chopping tools represent the Sohanian. These pebble tools were intended to be use for the purposes of cutting, chopping and scraping. But it should be noted that along with these pebble tools, thick flakes have also been found which were perhaps used for cutting meat and scraping hide. In fact, all these kinds of tools were the 'All-Purpose Tools' since at this point of time specialized tools were not made. A chopper is a unifacially worked pebble tool. The working edge was made by flaking at one side (unifacial) of the tool. The majority of choppers have a more or less transverse or straight cutting-edge. However, numerous choppers, tending-towards a pointed cutting-edge, are also found within the pebble tool assemblages.

A chopping tool is a bifacially worked pebble tool like chopper, it also has a transverse or straight cutting edge, but in this case the flakes were removed from both the surfaces of the pebble was not worked upon. The working edge of the chopping tool is formed by the intersection of the alternate flakes removed from both the surfaces and in two directions along one end or side of the pebble. The Sohan culture sites are found in Sohan valley, Potwar region, Beas valley, Narmada valley, etc.

The tool-kit of the Acheulian culture consists of a large variety of tools, such as handaxes, cleavers, choppers, scrapers, discoids, points, borers, polyhedrons, spheroids and others made on pebbles, cores and flakes. Of these types, handaxes and cleavers, in a variety of shapes and forms, were dominated.

The most diagnostic tool type is handaxe with its various subtypes. It is one of the standardised tool types and is invariably thick at one end (butt-end) and pointed, or else with small chisel-like edge, at the other end (tip)- Handaxes are made both on cores and flakes. They are bifacial and in a variety of shapes, viz., pear, almond, oval and triangular. The next important tool type is cleaver. This cleaver is characterized by an axe-like broad cutting -edge that is at right or obtuse angle to the long axis. The majority of the cleavers are fashioned on thick and heavy or light flakes since these tools were used as axes, i.e., for cutting trees, plants, animal bodies, etc. They are broadly classified into two types on the basis of the shape of their butt-ends, viz., 'rounded butt' or 'U-shaped butt' and 'pointed butt' or 'V-shaped butt'. The cutting edge is straight, oblique or convex. The other main typological forms are choppers and scrapers, as have been mentioned earlier also.

On the whole, the appearance of choppers and handaxes in India is simultaneous. Cleavers, however, appear later than choppers and handaxes but within the Acheulian Culture. It is quite evident that during the Lower Palaeolithic times all the three major types, viz., choppers, handaxes and cleavers, were present and toolmakers were well acquainted with all these types. These tool types are found to occur in different proportions in the Lower Palaeolithic assemblages in different parts of the country.

Tools of the Acheulian Industries

No.	Early Acheulian	Late Acheulian
1	Inferior workmanship	Superior workmanship
2	Deep and irregular flake-scars	Shallow and regular flake scars
3	Thick body	Not so thick
4	Asymmetrical for	Symmetrical
5	Rough surface	Finer surface
6	Uncontrolled flaking	Controlled flaking
7	Stone hammer technique	Soft hammer technique
8	Handaxes,- flakes tools	Handaxes, cleavers, flake tools

Raw material

The raw materials used for tool making varied regionally, according to the geology of the area. In western Maharashtra, dyke basalt or dolerite was the only rock available. Over the rest of the country, quartzite was the preferred rock and occasionally quartz was also used. In the Hunsgi valley in Karnataka, limestone was the main raw material but occasionally basalt and granite were also used. In southern Kerala, leptynites were used. Coarse-grained granite was also used in northern Bundelkhand.

Developmental phases within Acheulian in Indian context, There are two developmental phases within the Indian Acheuiian, they are:

1) Early Acheulian and
2) Late Acheulian

Early Acheulian

It is characterized by inferior workmanship as revealed by deep and irregular flake-scars, thick bodies and asymmetrical forms. Lalitpur, Adamgarh, Kuliana, Chirki-Nevasa, Anagwadi, Hunsgi, Singi Talav near Didwana in Rajasthan, and many other sites in peninsular India yield early Acheulian type tools. These sites are characterized by high percentage of chopper-chopping tools and bifaces, low

percentage of non-biface tools made on flakes, high ratio of handaxes to cleavers, low percentage of blade-like flakes and Levalloisian flakes but predominance of stone hammer or free-flaking technique used for fashioning the tools.

Late Acheulian

This stage of development in the Acheulian industry is characterized by finely carved and shapely handaxes and cleavers. It is found at sites like Bhimbetka, Peera Nullah, Berach valley, Rallakalava valley, Attirampakkam, Vadamadurai, Raisen complex, Paleru, Gunjana, Gangapur, Malaprabha etc. These complexes are characterized by almost total absence of chopper-chopping tools, low percentage of bifaces, high ratio of cleavers to handaxes, very high percentage of and a great diversity among non-biface tools made on large flakes, high indices of flake-blades, (i.e., parallel-sided flakes and not true blades) and Levalloisian flakes and prominent use of soft hammer flaking technique to produce tool.

Location

Acheulian hunter-gatherer populations adapted themselves to a wide variety of environments or ecozones. These include the semi-arid regions of western Rajasthan, Mewar plain, Saurashtra, Gujarat alluvial plain, subhumid dry as well as moist deciduous woodland zone in central India, semi-arid Deccan plateau, Chhota Nagpur plateau and the Eastern Ghats, North of the Kaveri River.

In peninsular India, the Acheulian artifacts are usually found buried in boulder conglomerate or large pebble gravels, found in the lowest levels of the river-deposits (basal gravel) seen along the exposed banks of the Chambal, Son, Mahanadi, Narmada, Godavari and Krishna rivers and their tributaries. These gravel, are believed to have been deposited during the semi-arid climate with intermittent, erratic rainfall when there was sparse to practically no-plant cover, or very little of it.

Habitat

On the basis of geomorphic settings of sites and origin of associated deposits, Acheulian sites have been classified into five groups.

- Alluvial sites
- Coastal sites
- Slope sites
- Surface sites
- Rock-shelter and Cave sites

The first four groups fall into the category of open-air sites. Rock-shelter and Cave category of sites are few in number if not altogether lacking. The Acheulian man lived mostly close to the riverbanks, sea and lakeshores and in the foothills. Easy availability of perennial water supply, plant and animal foods and raw materials for manufacturing stone tools were the main considerations while selecting the occupation sites.

Makers of Lower Palaeolithic assemblage

The fossil of a hominid skullcap (partial cranium) was discovered in by Arun Sonakia (1982) of the Geological Survey of India in the Central Narmada valley at the site of Hathnora in Sehore district, Madhya Pradesh. The hominid fossil specimen from Hathnora is presently known as 'Narmada Man.'

The cramium was first assigned to 'Homo erectus' by Sonakia, but now some scholars like K.A.R. Kennedy and Arthray have assigned the Narmada Man to archaic Homo sapiens or *Homo Heldbrigansis*. So far, this appears to be the only evidence of a human skull of the early Prehistoric man in India. However, P. Rajendran of the Kerala University, Thiruvananthapuram has claimed to have found a fossilized skull of a two month old child in a secondary gravel deposit at Odai in Villupuram District in Tamil Nadu. He gave an affectionate name Laterite Baby to this skull.

In other parts of the world, especially in Africa, chopper-chopping tradition is ascribed to the *Homo habilis* who appeared on the earth prior to the arrival of the *Homo erectus*, the earliest ancestor of modern man. The handaxe tradition is sometimes attributed to the *Homo erectus*.

Faunal Remains from Lower Palaeolithic context

Faunal remains in the form of fossils of the extinct animals have been preserved in Acheulian-bearing gravels in peninsular rivers like the Narmada, Godavari, Kortallayar and their tributaries. These comprise wild boar (Sus namadictis), cattle (Bos namadicus), elephant (Elephas hysiidricus and Stegodon insignis ganesa), horse (Equiis namadicus) and hippopotamus (Hexaprolodon namadicits). The presence of fossils of the extinct animals indicates the existence both forest and open grassland environment and the availability of plentiful water round the year.

Paleoenvironments

Active research on vertebrate paleontology, and the paleoecology, morphology, and geographic distribution of Indian Pleistocene fauna has been carried out (Badam 1979). In northwest India, the Lower Pleistocene is characterized by the presence of Eqnus, Bos, Elcphns, and Rhinoceros, while in the Middle Pleistocene deposits of the Narmada Valley, Eifiuis. Bos, Eleplias, Sus, and Stegodon are found (Badam 1979). The climate during the Pleistocene varied between being warmer and more humid, and cooler and drier than today. The preserved fauna indicate the existence of both forest and open grassland environments and the availability of a plentiful water supply. The existence of such widely diverse climatic and environmental zones gave rise to a profusion of large and varied fauna. During the later stages of the Pleistocene, changes in the climate resulted in extinctions, but the nature and timing of the extinctions is unclear.

Acheulian sites occur in a wide variety of ecozones, including the semi-arid western Rajasthan, the Mewar Plain, the Gujarat alluvial Plain, the sub-humid dry and moist deciduous woodland zones; the Deccan Plateau, the Eastern Ghats, and the southeast coast (see Misra 1989). Direct evidence for ecological conditions during the Acheulian is limited, although settlement pattern data suggests that Acheulian populations occupied a variety of microhabitats. Today, these regions receive monsoonal rainfalls, have a thick vegetation cover, and are rich in wild plant and animal resources.

The best evidence of climatic changes and human responses to them during the Quaternary comes from the semi-arid zone of Rajasthan (Misra 1987; Misra and

Rajaguru 1989). At Didwana, Acheulian sites are located along lakes and pools in wide floodplains of shallow meandering streams, on stable dune surfaces, and on extensively exposed gravel beds (Misra 1987; Misra and Rajaguru 1989). The climate during this period was essentially semi-arid, but it fluctuated several times between cool and dry and warm and wet. During cool and dry phases, extensive and thick deposition of sand sheets and sand dunes occurred, while during wet and humid phases, the dunes were stabilized. While no faunal or plant remains have survived in fluvial and aeolian sediments, high site density strongly implies that this was a favorable ecological zone. In the Vindhya Hills, rockshelters were inhabited by Acheulian groups (Misra 1987), and nearby, there are many open air sites (Jacobson 1985). Misra (1989) has suggested that these represent seasonal camps, the rockshelters being used during the rainy season and the open air sites during the winter months.

Dates of Lower Palaeolithic sites.

Our knowledge of the antiquity and duration of the Lower Palaeolithic Culture in India is far from satisfactory The antiquity of Stone Age man in India now goes back to only a little more than half a million years from now, about 6 lakh (6,00,000) years as the radiometric dates on volcanic ash from Bori in Maharashtra would indicate. The present semi-arid climate of central and western India and the Deccan is thus 6 lakh years old, and this is roughly the date of the arrival of Lower Palaeolithic hominin in this region as the discovery of Acheulian stone artifacts from Bori (Maharashtra) indicates. The calcritised soils and other alluvial sediments from Bori were dated by Ar/Ar method.

Another important Lower Palaeolithic site in Maharashtra, which has been explored intensively, is Nevasa, Dt. Ahmednagar. It is dated to about three and half lakh (3,50,000) years and to the same age belong the Lower Palaeolithic stone tools found in Gujarat. The miliolite limestone at Junagadh in Saurashtra, occurring at 20 m above mean sea level, and the tools from Valasana in the Sabarmati valley belongs to the same age as the TL dates indicate.

In Rajasthan, a fossil dune at Didwana was subjected to scientific excavation. A 20 m deep trench called "16 R\ excavated on the dune revealed three major units of stone artifacts, belonging to the three different phases of the Palaeolithic age; the

Lower, the Middle and the Upper They were found at a depths of 18 5 m, 115 m and 5.5 m, respectively. The earliest tools of the Lower Palaeolithic were dated by TL method to 1,91,000 to 1,40,000 years BP. This time period corresponds with the third glaciation (Riss) in the temperate lands of Europe. It was a period of intense cold as a result of which much of the water was locked into ice, resulting in lowering of sea levels by as much as 100 m or so It must be noted that scientists have observed that when the temperate zone experiences glaciation, the tropical countries like India suffer droughts

It is likely that with the refinement of dating techniques and their application to more sites, the antiquity of the Lower Palaeolithic in India may go back to the Lower Pleistocene, i.e., between 2.0 and 0.7 million years because the stone tools comprising simple cores and flakes (Mode 1) found from Riwat, near Rawalpindi in Pakistan have been dated to 2 million years (Rendell and Dennell 1985; Rendell *et al* 1987), and the Isamapur comprising handaxe and cleavers of Acheulian type (Mode 2) have been dated to 1.2 million years (Paddayya et al. 2002), otherwise most of the Indian Lower Palaeolithic are dated from >150 to >350 kyr. The upper limit of the Acheulian culture is equally somewhat not very precise. However, since at many sites the Acheulian grades into the Middle Palaeolithic and since the absolute dates of the ideal Palaeolithic sites range from ca. 150,000 to ca 20,000 BP, it is quite likely that the Acheulian tradition persisted, at least in some areas, well into the Upper Pleistocene.

3.3. Middle Palaeolithic industrial complex

Till about the middle of the twentieth century, prehistorians generally thought that in the development of Indian Stone Age cultures there was no Middle Palaeolithic culture comparable to Europe. Till this time, only at a few places, such as Sohan valley and Narmada basin, discovered by de Terra and Paterson in 1939, at Kandivali near Mumbai by Todd in 1938, and in Kurnool district in Andhra Pradesh by Cammiade and Burkitt in 1930, some flake tools, characteristic of the Middle Palaeolithic culture were discovered.

The tools of this culture were, however, also discovered at Nandur Madhmeshwar on the Godavari, Nasik district, Maharashtra in 1943, but doubts still persisted. The credit for the identification of the Middle Palaeolithic culture in India

in fact goes to H.D. Sankalia who discovered a flake industry comprising scrapers, points and borers made on siliceous materials like chert, chalcedony, agate and jasper in the stratified deposits (Gravel II) of the Pravara at Nevasa in 1955. He named it 'Series II' of the Palaeolithic artefacts, Series I being the handaxe-cleaver industries of the earlier period. Subsequently, similar artefacts were discovered in different parts of peninsula. As in the early phase of these discoveries, the nomenclature of Indian Palaeolithic cultures was not finally settled, these were ascribed various names like the Middle Palaeolithic, Middle Stone Age, Series II, Nevasian, and Flake Culture by different scholars for the simple reason that it was felt by some scholars in India, including Sankalia, that Indian situation was different from the European, India did not witness the classical European Middle Palaeolithic. However, after a lot of debate, spanning over at least a decade or more, it was agreed that India too had its own Middle Palaeolithic.

The Middle Palaeolithic sites are generally distributed in the same area where the Lower Palaeolithic sites are located, indicating thereby that the Middle Palaeolithic population occupied the same areas and the Middle Palaeolithic culture evolved from the Lower Palaeolithic culture. The Lower Palaeolithic Acheulian culture developed slowly and gradually into the Middle Palaeolithic by shedding some of the older tool types, and also by evolving new forms and new techniques of making them.

The Middle Palaeolithic culture developed during the Upper Pleistocene, a period of intense cold and glaciation in high altitudes and northern latitudes. Areas bordering glaciated regions, however, experienced strong aridity. That is perhaps the reason why Middle Palaeolithic sites arc comparatively sparse in western Rajasthan, the Mewar plateau and the Gujarat plains. In India, Middle Palaeolithic assemblages have been reported from Luni valley, around Didwana, and around Budha or Old Pushkar in western Rajasthan, at numerous sites in the valleys of the Chambal, Son and Narmada and their tributaries in Central India, as well as from the Chhota Nagpur plateau, on the Deccan plateau, and the Eastern Ghats.

The Middle Palaeolithic sites are found located in the open-air along perennial as well as seasonal streams, along hill slopes and on stable sand-dune surfaces as in western Rajasthan, and in rock-shelters as in central India. Evidence from the site of Samnaur in Narsinghpur district, Madhya Pradesh shows that in this

case Middle Palaeolithic groups camped on high alluvial, away from the river channel and close to the hills.

Raw Material

The chief raw materials used for making the tools of the Middle Palaeolithic culture consist of chiefly cryplocrystalline silica of various kinds, often called 'semi-precious stones', such as agate, chert, chalcedony and jasper, which, when struck to produce tools, have a smoother and more regular conchoidal fracture than the somewhat granular quartzite of Lower Palacolithic tools. This enchorial fracture helps to produce fine small Hakes due to which the tools are smooth in touch and shapely in form. The raw materials were available handy by the human beings in the riverbeds in the form of pebbles and also in the form of broken rocks in the fields through which they are seen cropping up as veins; particularly quart/. Occasionally, fine-grained quartzite was also employed for making tools. This variation in raw materials was probably due to changed environment, and typo-technology, which are intimately linked with the ways of life of the people in which hunting of small animals seems to have replaced the hunting of big animals of the Lower Palaeolithic period.

Stone tool types from Middle Palaeolithic

The use of bifaces (handaxes and cleaver) as also of heavy core tools like choppers, polyhedrons and spheroids slowly disappeared. Instead, tools made on flakes and flake-blades (parallel-sided thin flakes) became more common. Side scrapers of various types, end-scrapers, denticulates, notched scrapers, points and borers are the most common tool types of this period. These were made by the application of retouch, i.e., by finely trimming the edges of parent flakes by the removal of tiny thin flakes or chips, apparently to strengthen the cutting edge of the tool- Many of the scraper forms are believed to have been used for manufacturing wooden tools and weapons of chase and also for processing animal hides. Some of the points were perhaps hafted in wooden shafts for use as spears. Gradually, the tools become smaller, thinner and lighter. Improved and much less muscle power requiring techniques of removing flakes from cores, such as the Levallois and discoid core techniques, were now used extensively- There was also a significant change in the choice of rocks for making tools. While quartz, quartzite and basalt

continued to be used, in many areas they were supplanted in varying degrees by agate, chert, jasper, chalcedony and other fine-grained siliceous rocks.

Scrapers of various types predominate the Middle Palaeolithic cultures. They may be concave or hollow, convex, concavo-convex side, round-end, etc. made on simple flakes, flakes with prepared platform or flat nodules and sometimes on the long edges of the blade-flakes. Other tool types include borers, awls, scraper-borers, blade-like thick flakes of flake-knives of square, rectangular or crescent shape, chopper-chopping tools, discoids, small Acheulian type handaxes or bifaces, burins, etc. The stone points found in association with the scrapers may be simple as well as tanged, generally small. Some simple points were made by stone hammer technique while some others by developed and specialised Levalloisian and Mousterian techniques.

The tools may have been put to different purposes: the straight-sided scrapers for dressing skins and barks of trees, the hollow or concave type for smoothing the hafts of spear or arrowheads; the knives for cutting and chopping and the pointed tools for piercing wood, bone, soft stone and hide. These tools were also probably involved in the preparation of larger tools and weapons of chase of perishable materials like wood and bone. The carefully retouched and notched tangs of various types of leaf-shaped points or arrowheads were meant for hafting before they were used.

Geographical Distribution

Middle Palaeolithic sites have been discovered in the valley of the Luni and its tributaries in western Rajasthan. In the Luni valley, a great variety of materials has been employed for making tools, e.g., silicified wood, rhyolite, porphyry, etc. Small handaxes and cleavers still persist though not so numerous in any collection. However, the use of Levalloisian technique to produce tools was more dominant. The assemblage of tools here evolved clearly out of the Achculian tradition. From near the freshwater lake of Budha Pushkar (Alwar district), a Middle Palaeolithic industry, comprising scrapers, chopping tools, cleavers, blades, burins and prepared flakes, has been reported.

In Maharashtra, the Middle Palaeolithic tools occur practically all over the State. Stratified tools come from the Upper or Gravel II of the river deposits, which

is also rich in nodules of jasper, chalcedony, etc., which were used for the Middle Palaeolithic tools. The main sites are Koregaon, Chandoh and Shikarpur, all in Pune district; Rankenala in the Kan valley; Nevasa and Kalegaon in the Ahmednagar district: and Kandivali near Mumbai. The Middle Palaeolithic industry here is dominated by a variety of scrapers, borers and points. It may be noted that points with single or double tang are unique to Maharashtra.

In Andhra Pradesh, in the Chittoor and Kurnool districts, there are many Middle Palaeolithic sites represented by points and a variety of scrapers. In Karnataka, the Middle Palaeolithic industry is based on chert, though occasionally quartz and quartzite are also found. Many sites, like Taminhal, Anagwadi, etc., are rich both in the Lower and Middle Palaeolithic tools. The Gulbarga, Bellary and Bijapur districts have also provided many Middle Palaeolithic assemblages with tools such as scrapers, points and borers.

Tamil Nadu is also rich in such sites. K.D. Bancrjee excavated the sites of Attirampakkam and Gudiyam. These excavations show a stratigraphic succession of the Acheulian and the Middle Palaeolithic flake-scraper industries.

Faunal Remains from Middle Palaeolithic period

The fossils of the faunal remains from the upper Group of the Narmada alluvium comprising wild horse (Equus namudicus}, wild cattle (Bos namadicm) hippopotamus (Hexaprotodon palaeindicus), wild elephant (Elephas hysudricu.v), Stegodon insignia ganesa and Cervus sp. suggest a savannah grassland environment interspersed with swamps and forests. A variety of dcers may be assigned to the Middle Palaeolithic. They include the barking deer, hog deer, antelope, gazelle, nilgai, sambar, barasingha. etc. According to G.L. Badam, these may have evolved indigenously Stone Age faunal remains have also been reported from Bengal and Orissa, but it is enigmatic that similar evidence is lacking in Rajasthan and Gujarat. Kalegaon in Maharashtra has yielded extremely interesting evidence where a few stone tools were found embedded in the skull of a wild bull (Bos namadicus) which indicates the function of the tools and their contemporaneity.

Palaeoenvironments

The Middle Palaeolithic culture developed during the Upper Pleistocene, a period of intense cold and glaciation in the northern latitudes. Areas bordering glaciated regions experienced strong aridity, as noted earlier. The stratigraphical evidence of the huge gravel and sand deposits, in which Middle Palaeolithic tools occur indicates that rivers in India and Pakistan were then running in full force, sometimes even overflowing their banks as the high-level gravel suggests. These indicate a wetter climate with probably higher rainfall than at present and consequently there must have been good vegetation cover which provided plentiful plant and animal food, more particularly by way of small game hunting It is noteworthy that the Middle Palaeolithic sites have been generally found to occur not in thick forests, but rather close to riverbanks and gentler hill slopes nearby. In Rajasthan, they are situated on sand-dunes and in rock-shelters in the Narmada valley in central India.

Dates of Middle Palaeolithic sites

The Middle Palaeolithic in India begins by about 1,30,000 years ago in India. Several thermoluminiscence and Th230 / U234 dates from 16R dune profile at Didwana range from 150,000 to 100,000 BP. Over twenty radiocarbon dates obtained, mostly on shell and bone from sites in the northern Deccan and central India, range from 40,000 to 10,000 BP. This shows that the Middle Palaeolithic assemblages persisted over a long period of time, from the late Middle Pleistocene to the greater part of the Upper Pleistocene. It can be dated at least from 125ka (125,000) to 40ka (40,000B.P).

3.4. Upper Palaeolithic industrial complex

The Upper Palaeolithic is the most controversial and least known phase of Indian prehistory. Culturally, it is characterized by a new lithic tradition of blades and burins although a variety of other types, such as side-scrapers, end-scrapers, hollow scrapers, points, borers, etc. are also found in large quantities. However, the Upper Palaeolithic phase in India is neither geologically nor culturally well defined. There are only a few localities where the industries of this phase have been found in stratified deposits. On one end it is the continuation of the Palaeolithic cultures, and, on the other end, it merges with the Mesolihic cultures.

In Andhra Pradesh, these include the sites of Renigunta, Erragondapalem and Vemula, Gundlakamma valley and the limestone caves in the Kurnool district, the Gambheeram valley in Visakhapatnam, and the Paleru valley in the Prakasam district. Sites in Karnataka include Shorapur Doab and Salvadgi, and in Maharashtra, Inamgaon in Pune district. Other sites include Bhimbetka rock-shelter sites in the Raisen district of Madhya Pradesh, the Belan valley south of Allahabad in Uttar Pradesh, Singhbhum in Bihar, and a few sand-dune sites in Gujarat and Rajasthan.

The first indirect reference to the existence of Upper Palaeolithic in India was made by Robert Bruce Foote. He claimed to have discovered a few bone implements from Billa Surgam cave in Kurnool and thought them to be comparable to Magdalenian of France (Magdalenian is one of the Upper Palaeolithic cultures of Europe characterized by a large number of decorated bone tools besides tools made on stone blades). Later, Todd reported, one 'Series III,' same as Upper Palaeolithic assemblage, from the stratified deposits at Kandivali, near Mumbai, which is characterised by blades and burins. A few other stray finds have been reported by S.P. Gupta from Jabalpur region, by Malti Nagar from Ahmednagar, Maharashtra and by K.V. Raman from Madurai district of Tamil Nadu. A good number of artefacts from stratified deposits have been recovered by Issac from Kurnool district, A.K. Ghosh from Singhbhum district of Bihar, G.R. Sharma from Belan basin, M.L.K. Murthy from Chittoor district of Andhra Pradesh and K. Paddayya from Shorapur Doab of the same state.

M.L.K. Murthy and V. Rami Reddy were the first to plead for a well-defined place for the blade-and-burin industry of the Upper Palaeolithic in India. Upper Palaeolithic of India is, however, variously referred to by various scholars, as Series III/flake-blade/blade-tool/blade-and- burin/Upper Palaeolithic. However, now the term Upper Palaeolithic alone is used in preference to the rest of the terms.

Palaeoenvironment

The Upper Palaeolithic culture developed during the later part of the Upper Pleistocene. The climate of this period was characterized by extreme cold and aridity in the high altitudes and northern latitudes. Palaeoclimatic research, including geomorphology, sedimentology, and pedology as well as radiometric dating, such as

points, barbs, spatulae, worked bones, bone blanks, broken and cut bones and splinters. Such a rich assemblage of bone tools belonging to the Upper Palaeolithic has not been reported from any other site in India.

Upper Palaeolithic fireplace

In the Kurnool caves, an Upper Palaeolithic fireplace has been reported by Nambi and Murthy in a dated context In the excavation of a cave-complex, known as Muchchtla Chintamani Gavi, the evidence of fire activity has also been recorded which is found only in a few sites excavated so far. The structure of the fireplace is apparent between 1.50 m and 1.85 m, seemingly made by arranging limestone boulders in a horseshoe shape fashion.

Subsistence

From the foregoing account, an attempt may be made to reconstruct the life-ways of the Upper Palaeolithic populations in India. No human skeletal remain have been unearthed so far for this period that ranges from c. 40,000 years BP to 10,000 years BP. These hunter-gatherers had the knowledge of fire-making for cooking and for the production of artefacts. The discovery of a number of fiat grindstones, bored stones and anvils recovered in the Gunjana valley implies knowledge of processing vegetal foods like wild grains, and fishing activities as the bored stones would have been used as net sinkers as is done by the present-day food-gatherers like Yanadis in the area.

Faunal Remains from Upper Palaeolithic sites

Fossil faunal remains, including Canis sp,, Equus namadicus, Elephas sp.. Bubalus sp., Cervus sp., Bos namadicus, and Hexaprotodon palaeindicus recovered from the Belan, Mahanadi, Manjra, Godavari, Ghod and Krishna valleys, indicate a grassland ecosystem, with some forest cover, swamps and pools.

Dates of Middle Palaeolithic sites.

A number of radiocarbon dates from the Upper Palaeolithic sites, available from -Madhya Pradesh, Rajasthan and Maharashtra, suggest the duration of the Upper Palaeolithic from 30,000 BP to 10,000 BP. Many of the radiocarbon dates for the Upper Palaeolithic are >25 Kyr (less than 25,000 years; 1 K = 1000). The sites of Patne, Dharampuri and Bheraghat have been dated to more than 25 Kyr while the

sites of Nagda, Chandresal and Mehtakheri date between 30 Kyr and 40 Kyr. The dates for Inamgaon (approx. 21 Kyr) are among the youngest for the Upper Palaeolithic Phase in western India.

Chapter -3

An Overview of Raw Material and Technological Studies in Peninsular Palaeolithic

3.1. An overview on raw material studies

In recent years, there has been increasing attention being paid to several aspects of raw material and their relationship to lithic typology and technology. In recent years the Palaeolithic, suggest that many of the morphological and technological patterns observable in all lithic assemblages are the result of very fundamental effects that go beyond the factors of functions and style in explaining assemblage variability, are only visible once we are able to control for the effects of more fundamental factors like raw material variability.

It is know becoming clear that raw material variability has a considerable effect on lithic assemblage composition of lower and middle Paleolithic period.

There are several basic aspects of raw material, which are important, which includes quantity, availability, size and shape of the nodules and texture of the stone itself although most of these attributes still require much more quantification before their effects are fully understood.

Most of the work on raw material type has been based on four approaches namely (1) Inter- regional comparisons of raw material type and availability; (2) Intra- level comparisons of different raw material types; (3) The effects of distance from raw material source; (4) The fourth possibility that should be controlled, namely the continued exploitation of local raw material resources over geological time, this last approach was drawn by Dibble (1991)

The inter-regional studies of raw material variability are numerous and strongly suggest that the quality of local material, as well as the shapes and sizes of the nodules themselves, significantly constrain the rage of technologies employed as well as the final typological composition of the assemblages and in the intra-assemblages are mainly based on studies of imported raw material, affords an excellent opportunity to compare directly the differential utilization of one material versus another. The third approach which is based on the proximity of the raw material sources, where the variability in assemblage composition is related to the proximity to raw material sources and topography. The continued exploitation of local raw material resources over geological time is explained by the fact that diachronic industrial changes at a single site are usually not explained in terms of raw material variability because it is often assumed that local sources are constant.

However, there is the possibility that these sources do change significantly through times and this change can be due either to changing the climatic conditions affecting the exposure of local raw material sources (period of local erosion vs. deposition) and/or to continuous exploitation of local sources by the Prehistoric inhabitants. The exposure of local raw material may change significantly during the occupation of a site due to increased erosion or, conversely aggradation.

Three aspects emerge from studies based on the exploitation of local raw material resources over geological

- More intense use of the lithic resources, as reflected in a greater proportion of retouched pieces over all (as more of the available blanks are selected for retouching), and an increase in those types that reflect more intensive resharpening, rejuvenation, or reuse.
- There may be a gradual shift in the use of particular kinds of raw materials.
- There may be a general shift to more efficient technologies of blank production and or a change in technologies to accommodate lesser quality nodules.

Raw material availability is one factor, but another significant factor is occupational intensity. This factor may in turn be influenced by climate, group mobility, and site situation.

The design and assembly of lithic toolkits is mediated by a number of factors including the abundance and quality of raw materials available. In general, low raw material abundance and high raw material quality are thought to lead to formal tool designs, whereas high raw material abundance and low raw material quality lead to informal designs. Low raw material quality is seen as the overriding factor producing informal tool designs, even where raw material abundance low would favour formal designs.

Variability in raw material abundance leads to differences in the design and assembly of toolkits primarily as a function of energetic constraints. Technologies based on rare or exotic raw materials are expected to be designed to maximize core or tool use-life. Maximizing tool use-life cuts down on the costs of ''expensive'' long-distance raw material procurement forays (but see Binford, 1979). Formal core designs that maximize the ratio of edge length to volume of raw material, or tool designs that guard against breakage, for example, may be technological responses to

low raw material abundance. In contrast, minimizing raw material waste is not a major concern where raw materials are abundant in the environment. In such contexts, most toolkits are casual and display little effort to extend tool use-life. At the same time, abundant raw material provides a certain degree of flexibility to design formal toolkits if the need arises.

During last few decades more emphasis is given for the effect of raw material on the assemblage composition. This kind of study is lacking from India, very few scholars have taken up raw material as a important factor which has effect on the assemblage variability. Palaeolithic research in India is many based on the typo-technological studies and all researchers just talk about the types and distances from which these raw materials were brought. Very few scholars like Petraglia (1998), Paddayya (1989), Shipton (2004) and Pappu (2001) have emphasized the effect of raw material on the variability observed in the assemblage. In Palaeolithic studies in Peninsular India, not much work has been done on explaining the effect of raw material on the assemblage variability. These studies mainly concentrated on explaining more general aspects of raw material like the source of raw material, raw material type and how far the raw material is from the site, but, nobody has studied the effects of raw material on the assemblage composition.

3.2. Various types of raw material exploited by prehistoric people

The first concern of the toolmaker is to obtain good quality lithic material to manufacture stone tool. Raw material quality can be defined by identifying r quantifiable

It is well known from a long time that the quality of the material and the skill of the knapper, governs the shape and functional performance of the tool.

Raw material quality is most commonly associated with the mineralogical structure and purity of raw material. A high-quality raw material possesses little or no crystalline structure and contains few impurities, such as fossils or that would interfere with the direction of applied force. In this sense, raw material quality can be defined by identifying four quantifiable properties that characterize the workability of the material: (1) percent crystallinity, (2) average crystal size, (3) range in crystal size, and (4) abundance of impurities, such as fossils, veins of secondary crystals.

Ideal lithic materials are kinds of stone with the necessary properties of texture, elasticity, and flexibility. They must be of an even texture and relatively free of flaws, cracks, inclusions, cleavage planes and grains in order to withstand the proper amount of shock and force necessary to detach a flake of a predetermined dimension. When the required amount of force is applied to a properly prepared platform, a cone is formed and, therefore, portions of the stone can be removed producing flakes with a very sharp cutting edge. There is a relation ship to conchoidal fracture, but the final results depend on the surface and the conformation of the material. The termination and shape of the flakes are controlled by the desires and ability of the person applying the force and, therefore, do not always resemble the shell-like or conchoidal fracture.

The stoneworker's first concern in choosing working material is quality of texture and this is governed by the fineness or coarseness of the microcrystalline structure of the material. Generally, the coarser the stone texture, the tougher and more difficult it is to remove regular and uniform flakes. But, conversely, the platform prepared on coarse material will collapse more readily than that fabricated on finer textured material. Certain materials will allow the platform to collapse, leaving a dull edge. Others haven't sufficient strength or flexibility to permit detaching a long thin flake and will break off short causing multiple hinge and step fractures.

A toolmaker's criteria for identifying good lithic materials are: texture, luster, surface character, cortex, color, transparency, sound, flexibility, sharpness of removed flakes and perhaps most important, the amount of resistance to the necessary force required for detaching a flake. The degree of luster is used as a guide by the tool maker to determine if the stone will permit him to regulate the amount of force necessary to remove a flake of a given dimension, and is one of the most useful attributes for determining workability. Variations of luster include glassy, waxy, greasy, satiny to dull, matt, fiat, sugary, fine crystalline, medium crystalline, coarse crystalline and sandy.

Most types of suitable lithic materials have identifiable qualities recognized by the stoneworker. When choosing material, he will determine the homogeneity of the mass, appraise the texture and luster, and choose the raw

material of appropriate size to produce the size and type of finished tool he desires. A myriad of bright colors is desirable, but color, in most instances, does not indicate workability of stone. When making an appraisal of the workability of flint-like materials, one may first tap the stone (lightly to prevent bruising) and listen to the sound of the tapping, If the stone gives off a dull sound, one can expect undetectable cracks, fissures and planes of weakness. If the stone has a sharpring, however, the chances are good that the material will be of working quality. One may then remove a test flake, or cleave the stone to examine it further. If this shows the material to be free of crystal pockets, foreign deposits and shows the right luster, then the worker assumes the stone will lend itself well to the manufacture of on artifact. The final outcome, of course, will depend on the skill of the worker.

Majority of Lower Palaeolithic tools found from peninsular India are made from quartzite, except few sites from peninsular India which revealed the usage of different type of raw material, like from Hunsgi-Baichbal Valley, Lower Palaeolithic tools were made from locally found limestone. From the Middle Palaeolithic sites from peninsular India, a shift was observed in the preference for raw material type. Majority of Middle Palaeolithic sites from peninsular India revealed that flake tools which were manufactured at this site were made from cryptocrystalline silica variety of raw material (like chert and other siliceous variety of stones), but, many Middle Palaeolithic sites from peninsular India revealed a continuous usage of the same kind raw material which was used in the Lower Palaeolithic period (i.e., quartzite). Similar kind of pattern was seen in the Upper Palaeolithic tools from peninsular India.

3.3. Rock genesis

It is important to understand the genesis of rocks in order to understand how rocks are classified. The classification is based primarily upon composition and texture. Composition refers to the chemical elements from which rocks are created. These are usually determined by the identification of the minerals found in a rock. Texture refers to the size, shape, and relationship of individual particles in a rock. Both the composition and texture of rock are directly affected by its genesis or formational processes.

There are three broad families of rocks based upon genesis: igneous, sedimentary, and metamorphic.

Igneous rocks

Igneous rock is formed from cooled molten rock that can solidify deep beneath or on the surface of the Earth. Molten rock solidified on the Earth's surface is called lava; magma is molten rock that cools and solidities below the surface. Igneous rocks are divided into two groups, intrusive or extrusive, depending upon where the molten rock solidifies.

Extrusive, or volcanic, igneous rock is produced when magma exits and cools outside of, or very near the Earth's surface. These are the rocks that form at erupting volcanoes and oozing fissures. The magma, called lava when molten rock erupts on the surface, cools and solidifies almost instantly when it is exposed to the relatively cool temperature of the atmosphere. Quick cooling means that mineral crystals don't have much time to grow, so these rocks have a very fine-grained or even glassy texture. Hot gas bubbles are often trapped in the quenched lava, forming a bubbly, vesicular texture. Pumice, obsidian, and basalt are all extrusive igneous rocks. The cinder cone above and the close up at right are made of basalt.

Intrusive or plutonic igneous rock forms when magma is trapped deep inside the Earth. Great globs of molten rock rise toward the surface. Some of the magma may feed volcanoes on the Earth's surface, but most remains trapped below, where it cools very slowly over many thousands or millions of years until it solidify. Slow cooling means the individual mineral grains have a very long time to grow, so they grow to a relatively large size. Intrusive rocks have a coarse grained texture. The image at right shows granite, an intrusive igneous rock. Some examples for igneous rocks are as follows:

Volcanic rock is igneous rock that cools and solidifies at or very near the Earth's surface. Volcanoes produce volcanic rock. Granite is a coarse-grained intrusive igneous rock with at least 65% silica. Quartz, plagioclase feldspar and potassium feldspar make up most of the rock and give it a fairly light color. Granite has more potassium feldspar than plagioclase feldspar. Usually with biotite, but also may have hornblende. Lava is the magma that reaches the Earth's surface through a volcanic eruption. When cooled and solidified, forms extrusive (volcanic) igneous

rock and Pegmatite is a very coarse-grained igneous rock, commonly with a granitic composition. Usually forms from molten rock rich in water or other volatiles that facilitate the growth of large crystals.

Sedimentary rocks

Sedimentary rocks are formed from pre-existing rocks or pieces of once-living organisms. They form from deposits that accumulate on the Earth's surface. Sedimentary rocks often have distinctive layering or bedding. Many of the picturesque views of the desert southwest show mesas and arches made of layered sedimentary rock.

Clastic sedimentary rock

Clastic sedimentary rocks are the group of rocks most people think of when they think of sedimentary rocks. Clastic sedimentary rocks are made up of pieces (clasts) of pre-existing rocks. Pieces of rock are loosened by weathering, and then transported to some basin or depression where sediment is trapped. If the sediment is buried deeply, it becomes compacted and cemented, forming sedimentary rock.

Clastic sedimentary rocks may have particles ranging in size from microscopic clay to huge boulders. Their names are based on their clast or grain size. The smallest grains are called clay, then silt, then sand. Grains larger that 2 millimeters are called pebbles. Shale is a rock made mostly of clay, siltstone is made up of silt-sized grains, sandstone is made of sand-sized clasts, and conglomerate is made of pebbles surrounded by a matrix of sand or mud.

Of the fine-grained clastic rocks, only those that are very hard and brittle can be used for flintknapping. In other words, a conglomerate, breccia, sandstone, arkose, or graywacke is unsuitable for flint-knapping because the grain size is too large to allow control of the removal of flakes. Additionally, these rocks tend to fracture around the particles and do not break conchoidally. Siltstones and shales are composed of fine to very fine particles and are generally more suitable for production of chipped stone tools. However, unless the siltstone or shale is very hard, it tends to crumble around its grain particles upon impact, similarly to other kinds of clastic rocks previously mentioned. Therefore, only those very hard and brittle clastic rocks with a fine texture are good for chipped stone tool production. The strata within such clastic rocks must also possess uniform hardness and composition; if layers within a fine-grained clastic rock are of

differing hardness, the rock tends to break along bedding planes, a condition obviously detrimental to knapping (Andrefsky 1998).

Biologic sedimentary rock

Biologic sedimentary rocks form when large numbers of living things die, pile up, and are compressed and cemented to form rock. Accumulated carbon-rich plant material may form coal. Deposits made mostly of animal shells may form limestone, coquina, or chert. Depending upon the specific formation and context of genesis, cherts will occur in a range of colors and textures, and with various inclusions. Different trace elements and impurities within chert give it different colors and textures. The entire range of textures is all very smooth in relation to clastic rocks. Chert is homogeneous and individual particles or crystals are not visible without the aid of a microscope; it breaks with a conchoidal fracture.

Theories of chert formation processes are controversial and have changed rather drastically as new data have been gathered. Generally, it is now believed that most chert is formed in a deep-sea environment. Crystalline chert is precipitated from amorphous, soluble kinds of silica under the right pH and temperature conditions. More specifically, chert is formed through a sequence of silica transformation from opal-A to opal-CT to quartz (Williams and Crerar 1985). Approximately 80% of the silica found as opal-A is produced by silica-secreting organisms, specifically diatoms (Luedtke 1992:23). Diatoms remove silica from ocean waters and deposit it in the form of opal-A, As diatoms die and sink to the ocean floor their skeletons (made of opal-A) dissolve. Most ocean floors have high levels of dissolved silica, which is believed to originate almost entirely from diatoms (Siever *et al.* 1965). Ocean sediments are saturated with opal-A, which dissolves and precipitates as opal-CT. It is believed that opal-CT again dissolves and precipitates or recrystallizes into quartz under the right conditions (Luedtke 1992; Murata *et al.* 1977).

Chemical sedimentary rock

Chemical sedimentary rocks are formed by chemical precipitation. The stalactites and stalagmites you see in caves form this way, so does the rock salt that table salt comes from. This process begins when water traveling through rock dissolves some of the minerals, carrying them away from their source. Eventually

these minerals can be redeposited, or precipitated, when the water evaporates away or when the water becomes over saturated with minerals. Common forms of chemical precipitate rocks include halite or rock salt, gypsum, calcite or limestone, and chalcedony. Most chemical precipitates are relatively soft or dissolve easily in water and are not good raw materials for making chipped stone tools. Silicon dioxide (also known as quartz) is composed of silicon and oxygen, the two most common elements on the planet. Quartz occurs in hard mineral forms as well as in amorphous forms (known as opals). Opals (both opal-A and opal-CT) are unstable at temperatures and pressures found on the surface of the Earth (Luedtke 1992:7). For this reason the forms of quartz used for artifact production are of the hard mineral variety. Generally there are two forms of hard mineral quartz - macrocrystalline and microcrystalline. Macrocrystalline quartz occurs as a large free-standing six-sided crystal. Although rarer, these have been used as raw material for production of chipped stone tools (Reher and Prison 1991). Microcrystalline quartz, sometimes called crypto-crystalline quartz, is probably the most frequently used raw material for the production of chipped stone tools. This material is often referred to by locally or regionally designated names in the archaeological literature; it has been called chalcedony, flint, chert, jasper, agate, and a variety of other names.

Metamorphic rocks

Metamorphic rocks started out as some other type of rock, but have been substantially changed from their original igneous, sedimentary, or earlier metamorphic form. Metamorphic rocks form when rocks are subjected to high heat, high pressure, hot, mineral-rich fluids or, more commonly, some combination of these factors. Conditions like these are found deep within the Earth or where tectonic plates meet. In metamorphic rocks some or all of the minerals in the original rock are replaced, atom by atom, to form new minerals. Metamorphic rocks are often squished, smeared out, and folded. Despite these uncomfortable conditions, metamorphic rocks do not get hot enough to melt, or they would become igneous rocks.

Foliated metamorphic rock

Foliation forms when pressure squeezes the flat or elongate minerals within a rock so they become aligned. These rocks develop a platy or sheet-like structure that reflects the direction that pressure was applied in. Slate, schist, and gneiss (pronounced 'nice') are all foliated metamorphic rocks.

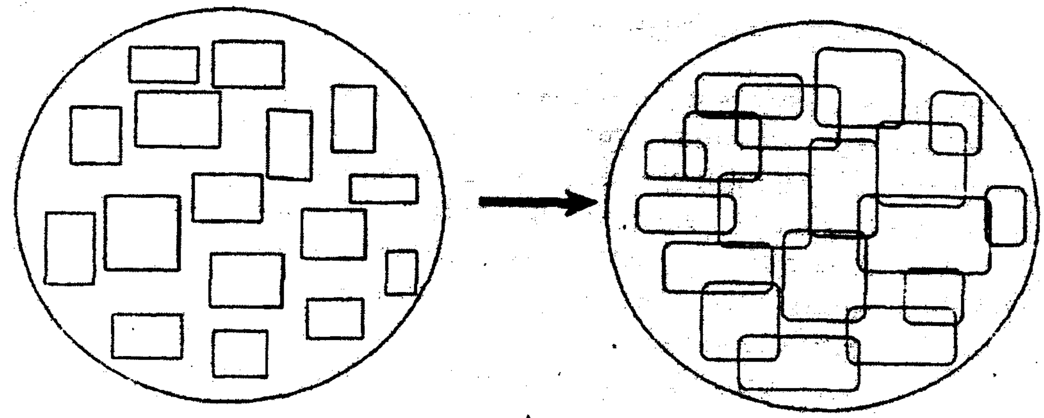
Non-foliated metamorphic rock

Non-foliated metamorphic rocks do not have a platy or sheet-like structure. There are several ways that non-foliated rocks can be produced. Some rocks, such as limestone are made of minerals that are not flat or elongate. No matter how much pressure you apply, the grains will not align! Another type of metamorphism, contact metamorphism, occurs when hot igneous rock intrudes into some pre-existing rock. The pre-existing rock is essentially baked by the heat, changing the mineral structure of the rock without addition of pressure.

The only structure that might appear in nonfoliated metamorphic rocks consists of elongated or deformed grains. Quartzites, marbles, and metaconglomerates are typical kinds of nonfoliated metamorphosed rocks. Of the three, only quartzites are frequently used as chipped stone artifactual material; metaconglomerates tend to be too coarse grained and marbles, although fine grained, tend to be too soft.

Quartzites formed as a result of metamorphism are called metaquartzites. These rocks are very hard because they tend to be made primarily from quartz. Typically metaquartzites result from deformed sandstones. As discussed previously, sandstone is a sedimentary rock composed of cemented beds of river or ocean sand. The sand grains tend to be particles of quartz. Sandstone, like most clastic sedimentary rocks, does not break with conchoidal fracture but instead tends to crumble around constituent sand grains. When sandstone is metamorphosed, however, the sand grains tend to interlock as a result of deformation (Figure 3.3.1a). When the hard quartz sand grains are interlocked, breaks tend to travel across the individual grains resulting in conchoidal fractures (Figure 3.3.1b). Sand grains are sorted into a range of different sizes and, as a result, some quartzites have extremely small quartz particles and others have particles that can be clearly seen with the

naked eye. Finer-grained quartzites tend to fracture with more control than the larger-grained quartzites and are more suitable for flintknapping.



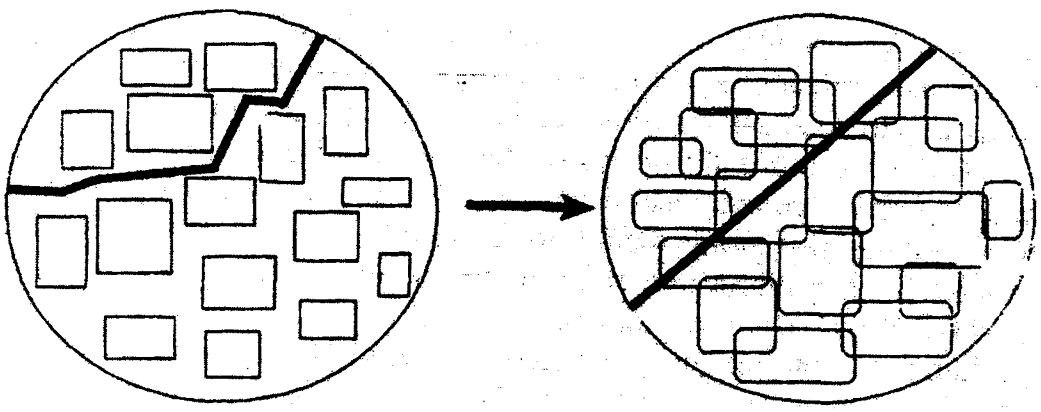


Figure 3.3.1. Schematic diagram of quartz particle deformation and fracture: (a) sandstone particles metamorphosed to quartzite; (b) fracture line breaking around quartz particles in sandstone and fracture line breaking across quartz particles in quartzite (adopted from Andrefsky 1998).

3.4. An overview on technological studies

"Technology" means the various processes that contribute to the production of stone tools, including strategies of manipulation and sequencing, knapping equipment, and knowledge of raw materials and operative forces. A technological system describes the dynamic and open interrelations of the material and behavioral components that serve to classify knowledge and techniques for the production of a specific technology. This definition of "technological systems" incorporates specific elements utilized by French cultural technologists (i.e., technological systems as a network of chaînes opératoires practiced by a group) (Lemonnier 1992; Roux 2003) as well as other researchers who employ a complex systems approach (i.e., open systems model and non-equilibrium) (Bentley and Maschner 2003; Van der Leeuw

and Torrence 1989). Technological analysis is concerned with the examination of the production of knapped-stone artifacts. There are many ways and methods to study stone tools and the debris from the manufacturing process. These are often complementary and therefore can provide a complex picture of the past lifeways and technologies. Currently, it is common that archaeologists study the entire "life cycle" of lithic material, from locating the raw material, through the procurement, manufacture and use, and up to the final abandonment of the artefacts. Furthermore, by studying the origin of the raw material it is possible to understand the patterns of human mobility and the mechanisms of exchange and interraction between the individuals and communities. The way lithics were reduced and tools produced can provide valuable information on their cultural affiliation and utilization. Observations pertaining to particular stages of the lithic chaîne opératoire, or reconstructions of the entire operational sequence at a particular site, can be used to develop a detailed understanding of past human cognitive capabilities, technological sophistication, mobility, and land use. Archaeological techniques for understanding prehistoric technology continue to include experimentation. The study of the attributes of waste products (debitage) and tools are the most important methods for the study of knapped-stone technology, backed up with experimental production. A very wide range of attributes may be used to characterize and compare assemblages to isolate (and interpret) differences across time and space in the production of stone tools. In order observe the technologyical changes, morphological measurmnent will provide an avenue to study the variations around an ideal type through time and the change from one ideal type to another. The pursuit of this theoretical model further requires methods that can identify the relative shapes of the ideal types and map their changes over time.

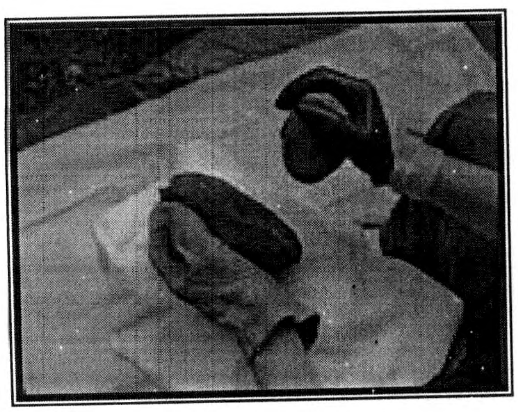
3.5. Techniques employed by hominins

Lithic reduction involves the use of a hard hammer percussor, such as a hammerstone, a soft hammer fabricator (made of wood , bone or antler), or a wood or antler punch to detach lithic flakes from a lump of stone called a core (also known as the "objective piece"). Flakes were removed from cores via percussion (hitting) the core with a hammer. Archaeologists have noted three different techniques for working rock to successive stages of refinement in the Palaeolithic Period.

Primary fabrication technique

Direct freehand percussion

This is a technique of holding the objective piece in one hand and striking with hammerstone or billet to detach flakes or blades. This technique prevailed during the entire Stone Age. The technique was used to make simple tools by striking vertically to the margin of a initial form with a hard hammerstone to remove rapidly expanding flakes with pronounced bulb of percussion and sharp edges (Figure 3.5.1). If the process is continued, the knapper can remove several flakes from the initial form and make large cutting tools. In order to manufacturer handaxe, the initial form is turned after each removal of flake and the previous flake removal is used as a striking platform for the next flake removal, by continually removing flakes from the initial form the knapper cold make a bifacial tool. Progressively through time, man improved his percussion methods and started using soft hammer like wood, antler and bone. This enabled the knapper to get a control over the flake removal. By using soft hammer medium shallow and long flakes were detached from the objective piece. This kind of technique was used in the late stage of Acheulian, by using this technique; hominins started making refined and more symmetrical large cutting tools.



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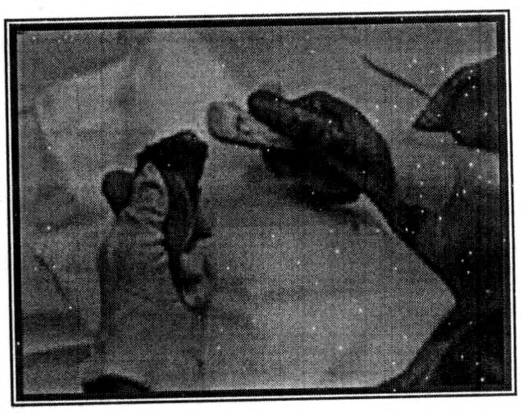

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Figure3.5.1. Example of direct percussion (a) hard hammer technique and (b) soft hammer

Indirect percussion

Indirect percussion is used for removing blades from the objective piece. The punch is a semi-pointed or blunt rod-like object of tenacious stone, bone, antler, horn, ivory or hard wood. The selection of the punch type depends on the quality of the raw material being worked, the technique and the knapper's preference. The precursor imparts the force through the punch to the established platform. This technique allows the knapper to accurately place the tip of the punch on the platform and maintain, with precision and control, a constant angle during the percussion. By using this technique Bordes and Crabtree (1969) removed uniform flakes and blades with small platform. For indirect percussion it is necessary to place the tip of the punch on the edge of the prepared platform of a preformed core or biface, depending on whether blades are to be made or the biface is to be thinned.

Pressure flaking

In lithic reduction, pressure flaking is a method of trimming the edge of a stone tools by removing small flakes by pressing on the stone with a sharp instrument rather than striking it with a percussor (Figure 3.5.2). This method, which often uses punches made from bone or antler tines, provides a greater means of controlling the direction and quantity of the applied force than when using even the most careful percussive flaking.Pressure flaking tools are of many materials and are of various forms and sizes. They range from a simple elongated pebble or deer antler tine to the more complex composite tools such as the elaborate pressure tools of the Arctic carved from ivory to fit the hand and with replaceable bits. Stone pressure tools are rare. The most commonly used were of organic materials such as bone, ivory, hardwood, horn, shell and whatever materials were available (Crabtree 1970). Pressure tools are used to apply force with accuracy and precision to the edge of the proposed artifact to detach controlled flakes. The pressure technique permits the kanpper to feel and control individual flake detachment to produce an artifact that is regular in form and with a sharp cutting edge. Pressure blades can be removed from a core by using a chest or shoulder crutch or a staff held by both hands. When using both hands, the core must be secured in a vise or clamp two logs lashed together with sinew and a stone used as a wedge to hold the piece, firmly in place (Crabtree 1968).

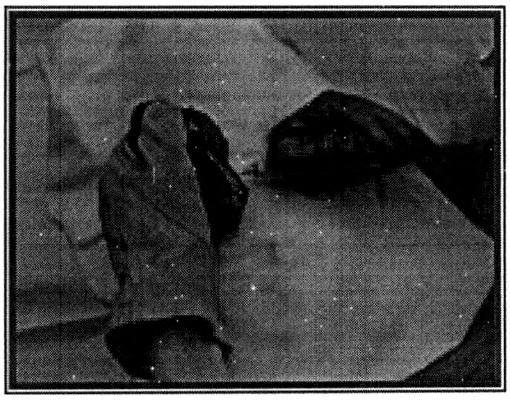

Figure 3.5.2. Example for pressure flaking.

There are many methods of detaching flakes random, parallel, diagonal, chevron, collateral, oblique, etc. But, technically, they all have basic methods that involve placing the pressure tool on a prepared or natural platform on the margin of the preform and applying pressing force to detach a flake on the obscure side. The varieties of pressure techniques are infinite and vary with (1) the knapper's design of the artifact, (2) combinations of inward and downward pressure, (3) various hand and body positions, (4) many designs of platforms, (5) use of supports such as anvils, hands, etc. , (6) varieties of pressure tools, (7) methods of holding, (8) superior and inferior lithic materials, and (9) intended function.

Method of Manufacture	Objective	Common Flake Characteristics	Common Implement
Hard Hammer	Often, but not invariably, the early stages of core reduction in order to assess and shape the core or produce a flake that can either be used immediately or after some further shaping.	Often, but not invariably, presence of cortex. Also, most hard-hammer flakes are larger than other types of flakes, and they often do not show much sign of earlier work on the core.	Often, a cobble or other rock with roughly the same density of the rock being flaked.
Billet	Sometimes, the further reduction of a core; more often, the second stage of shaping a flake tool, with thinning and edge shaping often undertaken.	Billet flakes are generally smaller and more delicate than those produced by the hard hammer, a result of the stone-worker being more careful in their shaping of the item. Billet flakes very often exhibit flake scars from previous flaking on their dorsal surface.	Billets are often made of antler or wood. They are generally less dense than the rock being worked; this is the origin of the term soft hammer.
Pressure Flaker	Fine-finishing stages of production, generally (but not exclusively) on flake tools as opposed to core tools, once initial shaping with the billet has taken place.	Pressure-flakes are generally quite small, perhaps less than a centimeter or so in maximum dimension, often appearing to be paper thin.	A common pressure flaking tool is the distal end of an antler tine. Bone and metal pressure-flakers are also used.

Chapter -4

Geological and Archaeological Context of Khyad, Benkaneri and Lakmapur in Malaprabha Valley (Kaladgi Basin)

4.1. Regional geology and geographical context

The Palaeolithic site of Khyad, Benkaneri and Lakhmapur are situated in the Malaprabha river valley of Kaladgi Basin. The Malaprabha Valley is located in Karnataka, South India. The Malaprabha Valley is part of the Eastern Karnatak Plateau, adjoining the Western Ghats. The area under study is drained mainly by the Ghataprabha and the Malaprabha rivers (major southerly tributaries of the Krishna river) and their major tributaries like the Hiranyakeshi, Tamraparni, Markendeta, Bennihalla, Hirehalla and Saraswati halla. The region is predominately underlain by gneissic rocks in the south, while its western edge is characterized by the rocks of the Dharwar series, and by lava outflows on the north and geographically, the Kaladgi basin forms the south central part of the Indian Peninsula. The central parts are crossed by the outcrops of the Bhima and Kaladgi formations. This varied geological foundation has greatly influenced its morphological aspects. An undulating black plain of the eastern plateau interspersed with residual hills, broad and fertile valleys and clusters of low hills on its western margin are notable geomorphic features.

The area under study lies in the central portion of the southernmost part of the Kaladgi basin. A look at the topographical sheet 48 M/5 and 48 M/9 immediately interest the observes to long and narrow ridges like hill chain which trends in the WNW-ESE direction and is situated on the southernmost part of the region. It stretches from Kolchi in the west to Lakhmapur in the east, and region to the north of it features a rolling topography dominated by the Lower Kaladgi Formation, characterized by prominent sandstone conglomerate outcrops with broad and flat upper escarpments. Joshi (1955:8) noted that the hilltops and the boulders which had fallen at the foot of the escarpments provided shelter for Paleolithic settlers. Pappu (1980), Korisettar and Petraglia (1993) noted that Mesolithic sites could be found in rockshelters and caves near the town of Badami. Further, to the south of the southern limits of the area, the Malaprabha river is mantaning the flow direction almost parallel to the trend of the hill ridge.

Geomorphologically the are is divisable into three latitudinal sections, each possessing its own characterstic features. The 3 sections are as follows;

1. the southern most hill range,
2. the central plain terrain, and

3. the northern flat-topped hill.

All sites for my study is from the southern most hill range (Figure 4.1.1). This is characterized by the development of narrow, elongated chain of hillocks, trending in general WNW-ESE direction. However, at Kolchi, the contours nearest to the Malaprabha river show a near N-S elongation (Hegde 1984). Further east of Narsapur, the hill range has a considerable change of trend, it being particularly east-west.

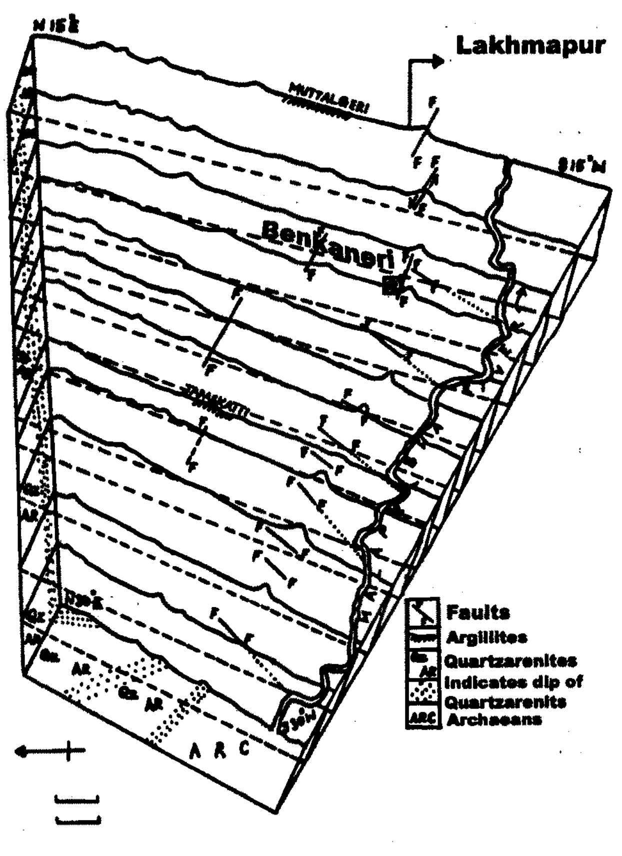

Figure 4.1.1. Block diagram showing the structure, the lithology and resultant geomorphological feature with sites located within them.

Geology of study area

The study are lies in the Middle Proterozoic (1600-1300 Ma) ovoid shaped Kaladgi Basin, exposed in the northern edges of the Dharwar Craton of Peninsular India. This Middle to Late Proterozoic epicartonic sediments have been divided into Bagalkot Group and the younger Badami Group (Jayaprakash *et al.* 1987). The lithounits in the district belong to Peninsular Gneissic Complex (PGC), forming the basement, followed by Hungund metamorphics, granites, Kaladgi Supergroup, Deccan basalts and younger intrusives. Isolated capping of laterite occurs at several places on Deccan Traps (Figure 4.1.2).

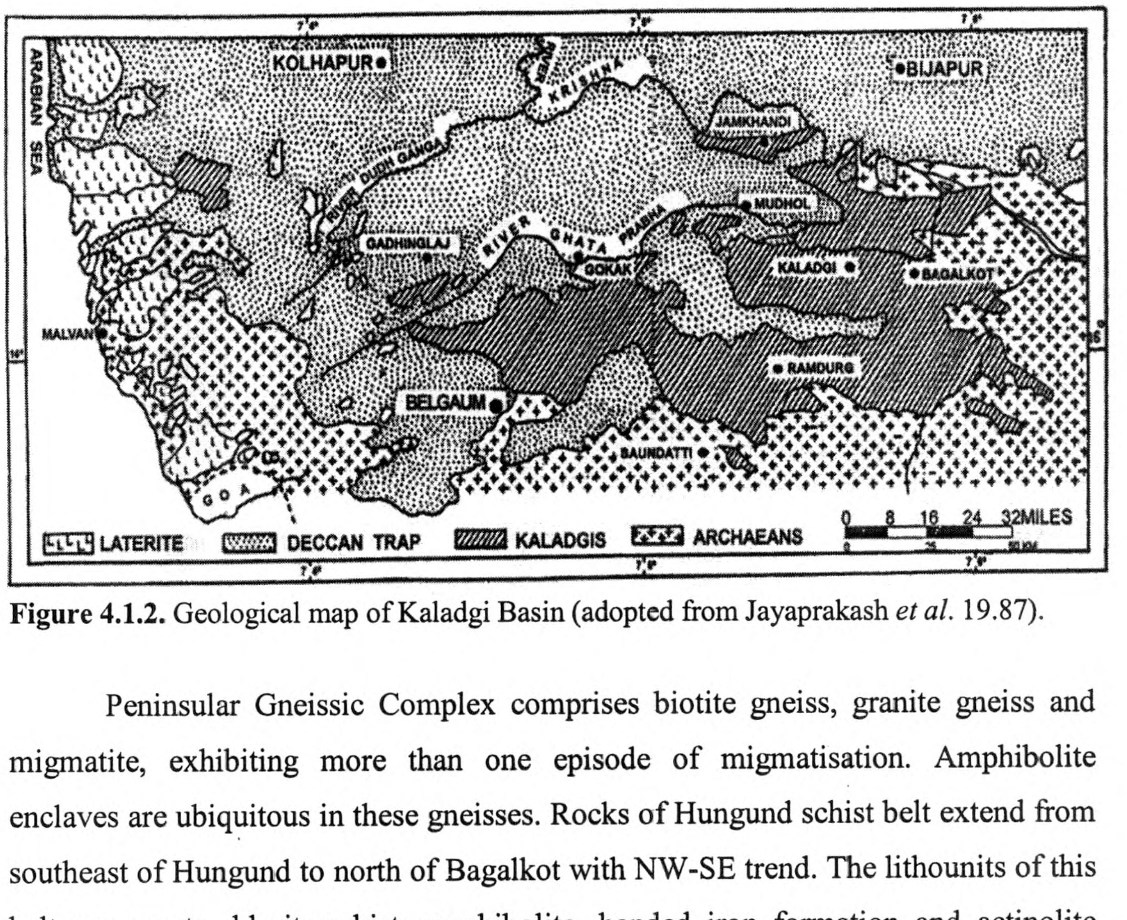

Figure 4.1.2. Geological map of Kaladgi Basin (adopted from Jayaprakash *et al.* 19.87).

Peninsular Gneissic Complex comprises biotite gneiss, granite gneiss and migmatite, exhibiting more than one episode of migmatisation. Amphibolite enclaves are ubiquitous in these gneisses. Rocks of Hungund schist belt extend from southeast of Hungund to north of Bagalkot with NW-SE trend. The lithounits of this belt are quartz-chlorite-schist, amphibolite, banded iron formation and actinolite schist. The Hungund metamorphics are intruded by pink and grey coarse grained granites which are considered equivalent to Closepet Granite. These granites are exposed to the south and east of Muddebihal, south of Guledagudda and south of Ilkal.

The sediments of Kaladgi Supergroup are divisible into lower Bagalkot Group and upper Badami Group. Bagalkot Group a deformed sequence is divided into Lokapur and Simikere subgroups. The lithofacies such as conglomerate-quartzite-argillite, dolomite, limestone, chert argillite are common and these

sequences repeated in cycles to form different formations. Rock types of Bhima Group more or less equivalent to Badami group are exposed around Muddebihal.

Deccan basaltic flows occupy the area to the north of R. Krishna and partially cover the rocks of Kaladgi and Dharwar Supergroups. The basalt flows, thoeliitic in composition, occur between 470-619 m above m.s.l. A few small irregular capping of laterite dot the trap country.

The geology of the region under study is comparatively simple, as it involves a few rock formations that differ in geologic age and they are as follows (Hegde 1984):-

Pleistocene and Recent	Black or red soils, calcareous tufa, brown sands, gravel-implementiferous.
Deccan Trap	Vesicular basalts of Ugalavat area
Minor acidic igneous activity and mineralization	Quartz veins, mineralization of calcite, baryte, micaceous hematite and yellow ochre.
Kaladgis (Precambrian)	Quartzarenites (grey, purple and colourless varieties), calcareous clayey quartzarenites, conglomerates, cataclasites, etc., argillites (grayish black and yellowish white varieties), and siliceous limestone
Archaeans including Dharwars	Eparchaean unconformity, schists, granite-gneiss, quartzites, etc. (granite-gneiss are exposed in the Malaprabha river beds at Khyad)

Lithostratigaphy of Kaladgi and Bhima Group

Recently Kaladgi has now been accorded a supergroup status consisting of a lower group for which the name Bagalkot Group has been given. The upper sequence in designated as the Badami Group. Recently four main facies of deposition have been recognized and these are-

1. Sandstone facies (dominantly quartzarenite with minor interbedded conglomerate and gravel beds)
2. Argillite facies (including siltstones and shales)
3. Chert breccia facies (poorly beded and silicified)
4. Carbonate facies (principally dolomite which are often cherty and stromatolithic)

The Kaladgi Basin is interpreted as an extensional tectonic basin. The four main microfaces are considerd to have been deposited simultaneously during the earliest transgression and their architecture has been governed by syn-sedimentary events of sagging of the basin floor along an array of east-west sagging of the basin floor along an array of east-west trending faults which dips to the north (Kale *et al.* 1996).

Conglomerate

This forms the basal component of the Kaladgi sequence and rests on the weathered edges of older gneisses. The conglomerate is composed of angular to sub-rounded cobble sized clast of quartzite, vein quartz and cherts.

Sandstone

This type of rock is the most abundant rock type in the Kaladgi sequence and which was used by the hominins. A good portion o the sandstone can be called quartzarenite, the rest being classed as quartzite-wacke. They are deposited in the shore regime, in beach-line, supratidal, dune, deltaic and sand-bar environment. Where sandstone dip steeply, they form continous ridges.

Argillites

Immediatlely follwing the quartzites are a well-developed sequence of argillites seen near Manoli. The argillite is brown to purple in colour with prominent bedding planes. These argillites are rich in carbonate. Locally they vary and grade into argillaceous grey micritic limestone.

Chert breccias

It is composed of pink cryptocrystalline silica in which angular fragments of chert are embedded. It is interpreted as representing washed accumulated

fragmentary debries, the result of episodic movement along basinal growth-fault subsequently subjected to chertification. These kinds of rocks were rarely used by the hominins at this region.

Dolomite

Beds of dolomite are well-developed and are of different shades of bluish to dark-grey and black. The rock is traversed by parallel banda of chert.

Limestone

Thick beds of limestone showing intricate fold patterns are prominent members in the Kaladgi sequence.

Intrusive igneous rocks

The only igneous intrusive are a dyke, not of great extent, seen between Lokapur and Holkundi.

Climate, rainfall and vegetation

The climate id moderately dry and hot the most part of the year. The hottest season in around the month of May with a temperature range of 35-40°C. The region receives scanty rainfall during the monsoon period, the average rainfall being about 60 cm. There is a very poor vegetation cover, it being mostly in the form of bushes, thorny shrubs etc.

4.2. Site description of Khyad: (N 15° 51′ ; E 75°42′)

According to Joshi the site Khyad was located on a major meander of Malaprabha river (Figure 42.1). The meander created extensive gravel spread ¾ km in length. The gravel yielded 100's of tools. The gravel bed was located in a side channel of the river and measured approximately 100m in length and 20m in width. The gravel bed deposited was situated below calcrete bearing soil and directly on bedrock (granite-gneiss) in places (Figure 4.2.2). The river bed section showed three stratums on top of the bed rock, the first stratum comprised of "black soil", second stratum consisted of brown sandy deposits and the third one comprised of old gravel conglomerate with Acheulian artifacts in them. This old gravel is intimately mixed with the boulders of the bedrock (granite-gneiss).

In order to discover sites away from river, Ravi Korisettar and M. D. Petraglia (1993) examined the area north of the main channel. An area measuring 0.5 square km was readily observed to contain Quaternary soil deposits. These deposits were underlying the black soil. Two strata were identified:

- Black cotton soil with calcrete, containing microliths.
- Calcrete deposit, containing Acheulian artifact.

When the present author visited this site the artifacts were noticed on the meander of the Malaprabha river as noticed by other scholars. In addition to artifacts found from the meander, many artifacts were also found from the dry river bed.

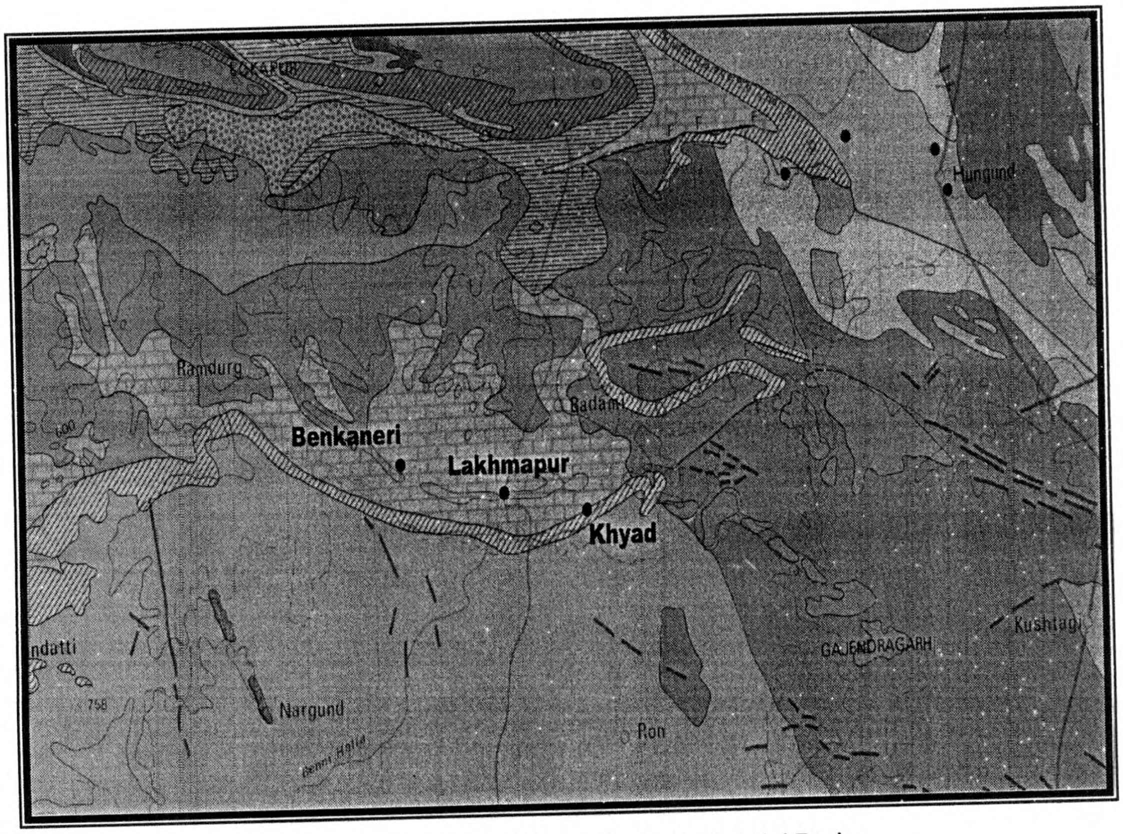

Figure 4.2.1. Location of Khyad site in the Kaladgi Basin.

Figure 4.2.2. Left bank of the river near Khyad, many large cutting tools were collected from this location.

4.3. Description of raw material types from Khyad

From this site five different types of raw material were exploited by the hominins and they are quartzarenites (quartzite), quartz, chert and chalcedony. These raw materials are readily available from the Kaladgi Basin itself. Two kilometer to the north of this site quartzarenites (quartzite) of Lokapur Subgroup of Kaladgi Supergroup are present in the form of escarpment. Due to the presences of beddings in these quartzarenites (quartzite), it gets weathered and comes out in the form of slabs and in the form of blocky clast. Chert and chalcedony are the two varieties that were exotic to this site and the closest occurrence of these two exotic raw materials are from Mahakut (approximately 11 km from the site) and Muttalgeri (approximately 13 km from the site). At Mahakut chert breccia are exposed and these chert breccia constitute of poorly sorted sub-angular to angular framework clasts ranging in size up to several tens of cm floating in a cryptocrystalline (jaspedious or chalcedonic) groundmass (Kale *et al.*, 1996). The rock formation at Mahakut is almost entirely composed of chert, with the microcrystalline silica forming pseudomorphs after the original framework clasts (Kale *et al.*, 1996). At Muttalgeri stromatolitic dolomites are profusely cherty in nature are found. This chert is of secondary replacement in origin and is not of primary deposit. Sandstone formations are noticed from Badami (approximately 11 km from this site) region these sandstones are of arenitic sandstone variety.

4.4. Lithic analysis from Khyad

This site revealed a total of 120 lithic artifacts having made on different grain size of raw material types. Most of the artifacts from this site were made on quartzarenites (quartzite) (117). Quartz (2) and dolerite (1) are the other variety of raw material that was used next to quartzarenites (quartzite).

Table 4.4.1. Frequency of flaked piece types broken down by raw material from Khyad.

Raw Material	Flaked piece Type			Total
	Large cutting tools	Broken large cutting tools	Chopper	
Dolerite	1 (0.94)	0 (0.00)	0 (0.00)	1 (0.83)
Quartz	2 (1.9)	0 (0.00)	0 (0.00)	2 (1.66)
Quartzarenites (quartzite)	103 (97.2)	14 (100)	4 (100)	117 (97.5)
Total	106 (88.33)	14 (11.6)	4 (3.3)	120

Table 4.4.1., provides tabulation of lithic assemblage composition by artifact forms and raw material types. Proportions are in parentheses by column. Based on the results summarized in Table 4.4.1., quartzarenites (quartzite) was the most preferred raw material, for manufacturing the large cutting tools. All large cutting tools which were collected from the river bed were 120 in total and from this 117 (97.5%) were made from quartzarenites (quartzite), 2 (1.9%) were made from quartz and only 1 (0.94%) were made from dolerite. Dolerite is non local raw materials for this site, these dolerite are found in the form of vein dyke from the adjoining area where granitic terrains could be noticed. From the river bed sit not even a single core was collected.

Table 4.4.2. Frequency of flaked piece types broken down by grain size from Khyad.

Grain Size of Raw Material	Flaked Piece Type			Total
	LCT's	Broken LCT's	Chopper	
<1/16 mm	2 (1.88)	0 (0.0)	0 (0.0)	2 (1.66)
1/16 to 2 mm	100 (98.1)	14 (100)	4 (100)	118 (98.3)
Total	**102**	**14**	**4**	**120**

The above table provides a comparison between grain sizes of raw material with artifact form. Proportions are in parentheses by column. The raw material with 1/16 to 2 mm (arenaceous) grain size was the most preferred raw material for all artifact forms. All large cutting tools were collected from the river bed and they were 120 in total, from this 118 (98.3%) were made from 1/16 to 2 mm grain size and only 2 (1.66%) were made from <1/16 mm.

4.5. Large cutting tool types at Khyad

From Khyad a total of 116 large cutting tool type were collected and from this 56 (48.3%) are handaxe, 25 (21.6%) are cleaver, 10 (8.6%) are biface, 9 (7.8%) are axe blank, 9 (7.8%) are cleaver blanks, 3 (2.6%) are pushplane, 2 (1.7%) are assayed core, 1 (0.9%) various biface and 1 (0. 9%) others and miscellaneous (Table 4.5.1).

Table 4.5.1. Frequency of large cutting tool types from Khyad.

Large Cutting Tool Type	Frequency	Percent
Assayed Core	2	1.7
Handaxe	56	48.3
Axe Blank	9	7.8
Cleaver	25	21.6
Cleaver Blank	9	7.8
Biface	10	8.6
Pushplane	3	2.6
Various Biface	1	0.9
Other & Miscellaneous	1	0.9
Total	**116**	**100**

Table 4.5.2. Frequency table of large cutting tool types broken down by raw material types at Khyad.

Large cutting tool type	Raw Material			Total
	Quartzarenites (quartzite)	Quartz	Dolerite	
Assayed Core	2 (1.7)	0 (0.00)	0 (0.00)	2 (1.7)
Handaxe	54 (47.7)	2 (100)	0 (0.00)	56 (48.3)
Axe Blank	9 (7.9)	0 (0.00)	0 (0.00)	9 (7.8)
Cleaver	25 (22.2)	0 (0.00)	0 (0.00)	25 (21.6)
Cleaver Blank	9 (7.9)	0 (0.00)	0 (0.00)	9 (7.8)
Biface	10 (8.8)	0 (0.00)	0 (0.00)	10 (8.6)
Pushplane	2 (1.7)	0 (0.00)	1 (100)	3 (2.6)
Various Biface	1 (0.9)	0 (0.00)	0 (0.00)	1 (0.9)
Other & Miscellaneous	1 (0.9)	0 (0.00)	0 (0.00)	1 (0.9)
Total	113	2	1	116

At Khyad quartzarenites (quartzite) was used profusely used and dolerite as well as quartz was used in minimum numbers (Table 4.5.2). From 120 large cutting tools, 117 (97.5%) were made in quartzarenites (quartzite), 2 (1.6%) were made on

quartz and 1 (0.83%) was made on dolerite. Except 2 (3.6%) handaxe, which was made on quartz and 1 (33.3%) pushplane, were made on dolerite (Table 4.5.2).

4.6. Non-metrical attributes of large cutting tools

Common non-metrical attributes like cortex %, cortex type, flake type, initial form, breakage, tip shape, profile form and cross section were recorded for large cutting tools. In order to see the taphonomic details of the large cutting tools, degree of edge rounding and degree of patination was recorded. Simple bar charts and box plots were used in order to explain these non-metrical attributes.

Cortex type for large cutting tool types

Cortex type is recorded in order to see preference of hominins, for, selection of raw material clast type i.e., whether they preferred angular or rounded clast type to manufacture the large cutting tools. From 120 large cutting tools only 50 (41.66%) had the information on the cortex type. Figure 4.6.1., indicates that the hominins at this site preferred angular types and the next preferred cortex type was sub-rounded clast type and is followed by rounded and sub-rounded clast. More than 5 large cutting tools had no or little information on the cortex type and they are included in the indeterminate types. Table 4.6.1., is a cross tabulation for cortex type with large cutting tool types. From this table it is clear that out of 50 cortex types 29 (58%) large cutting tools were made from angular, 8 (16%) were from sub-rounded, 4 (8%) were from rounded, 1 were made from sub-angular and from 8 (16%) large cutting tools had little information on cortex type, which could not be grouped in any cortex type, so they are grouped in indeterminate types. Out of 120 large cutting tools 50 (41.7%) had cortex type information and from these 50, 25 (50%) of them were handaxes, in which 14 (56%) were made from angular clasts type, 4 (16%) from sub-rounded clasts, 3 (12%) from rounded and 4 (16%) from indeterminate. These 4 handaxe which are grouped in indeterminate clasts type had very little information on cortex type. Out of 6 axe blanks, 2 (33.3%) were made from angular clasts, 1 (16.6%) from sub-angular, 2 (33.3%) from sub-rounded and 1 (16.6%) from rounded. Cleavers are 8 in numbers and from these 6 (75%) were from angular, 1 (12.5%) from sub-rounded and 1 (12.5%) from indeterminate. Among 4 cleaver blanks that were collected from Khyad, 2 (50%) of them were made from angular and another 2 (50%) from indeterminate types. The bifaces were 4 in total and

among which 3 (75%) were made from angular and rest 1 (25%) from indeterminate. Various biface, pushplane and assayed core are the other tool types and from them, the 2 that were made on angular are the various biface and assayed core types and remaining 1 from sub- rounded is belongs to pushplane type.

Table 4.6.1. Frequency table of cortex types for large cutting tool types at Khyad.

Cortex Type	Handaxe	Axe Blank	Cleaver	Cleaver Blank	Biface	Various Biface	Pushplane	Assayed Core	Total
Angular	14 (56)	2 (33.3)	6 (75)	2 (50)	3 (75)	1 (100)	0 (0.0)	1 (100)	29 (58)
Sub-Angular	0 (0.0)	1 (16.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2)
Sub-Rounded	4 (16)	2 (33.3)	1 (12.5)	0 (0.0)	0 (0.0)	0 (0.0)	1 (100)	0 (0.0)	8 (16)
Rounded	3 (12)	1 (16.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (8)
Indeterminate	4 (16)	0 (0.0)	1(12.5)	2 (50)	1 (25)	0 (0.0)	0 (0.0)	0 (0.0)	8 (16)
Total	25	6	8	4	4	1	1	1	50

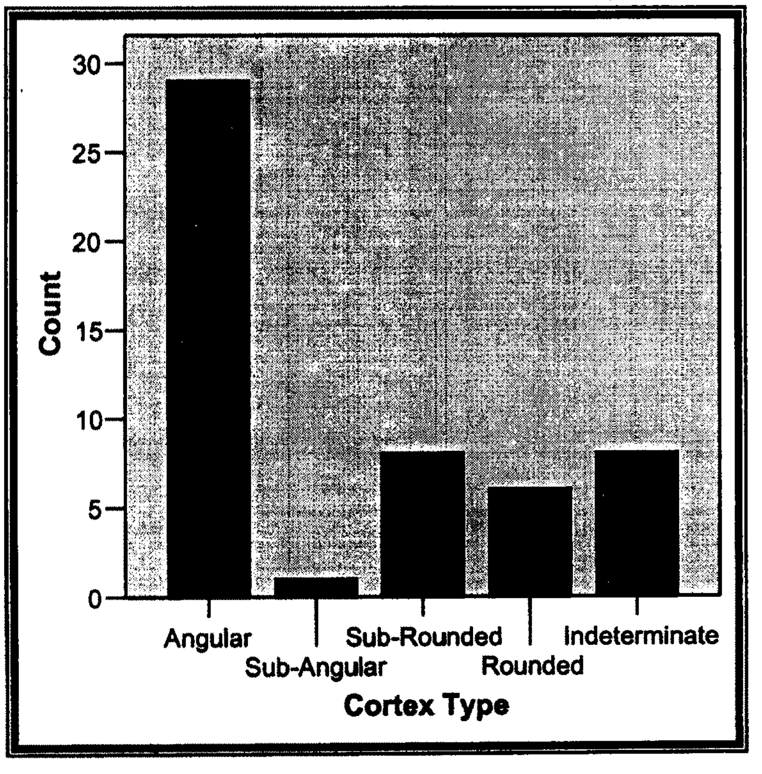

Figure 4.6.1. Bar graph of cortex types from Khyad.

Flake type for large cutting tool types

This attribute was recorded in order to find out the information on initial forms of the large cutting tools, if they were made from flakes. There are two types of flake namely end struck and side struck and one more category added was indeterminate, which had no information on platform and bulb of percussion, but had little information on the flake orientation.

Table 4.6.2., shows clearly that, from 116 large cutting tool types, 35 of them had information on flake types from which these large cutting tools were made. From these 35 large cutting tools 2 were biface, 23 cleaver and 9 cleaver blanks which had information on the flake types. Among the 2 bifaces, 1 was made from end struck flake and other was from side struck flake and from the 23 cleavers, 11 of them were made from end struck flake, 8 from side struck and 4 from indeterminate types. Cleaver blanks which were collected are 9 in numbers, from which 3 were made from end struck flake and 6 from side struck flakes.

Table 4.6.2. Frequency table of flake types large cutting tool types at Khyad.

Flake Type	Biface	Cleaver	Cleaver Blank	Total
End Struck Flake	1(50)	11(47.8)	3(33.3)	15(42.8)
Side Struck Flake	1(50)	8(34.8)	6(66.6)	15(42.8)
Indeterminate	0(0.0)	4(17.4)	0(0.0)	5(14.28)
Total	**2**	**23**	**9**	**35**

Initial form for large cutting tool types

Initial form refers to the initial point from which the flaked piece was made. Initial form categories includes pebble, cobble, slab, blocky, flake, and indeterminate. Pebble, cobble, and slab were identified by the presence of cortex on the artifact. Flakes were identified by the presence of one or more attributes, including presence of platform, bulb of percussion, flake release surface, and ripples on the convex ventral surface.

From this site large cutting tools were made on cobble, blocky, slab, heat spall and flakes. Some of the large cutting tools had no information on initial form or else the type of initial form couldn't be recognized and they come under the

indeterminate category. These initial revealed the preference for selection of raw material types by the hominins of this site. Table 4.6.3., reveals majority of large cutting tools were made from flakes (55.2%) and 34 (28.4%) had minimum or else no information on initial forms because these large cutting tools were completely flaked. The next preferred initial form was slab with 8.6%, cobble with 2.6%, blocky with 3.4% and the least among all the initial forms was heat spall with 0.86%.

Table 4.6.3. Frequency table for cortex types used to manufacture large cutting tool types at noticed at Khyad.

Initial Form	Frequency	Percent
Cobble	3	2.6
Blocky	4	3.4
Slab	10	8.6
Flake	64	55.2
Indeterminate	34	28.3
Heat Spall	1	0.86
Total	**116**	**100**

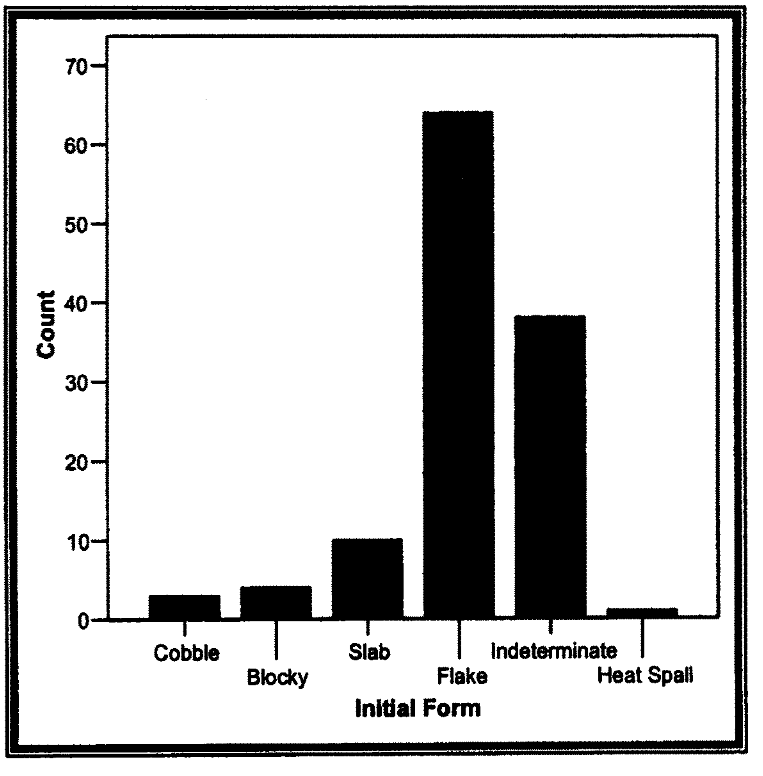

Figure 4.6.2. Bar graph for cortex types used to manufacture large cutting tool types at Khyad

Table 4.6.4., provides the information on the selection of initial forms to manufacture the large cutting tools. From the whole large cutting tool types (120), handaxes were the frequent tool types with 46.66% and of these handaxes, 24 (42.85%) of them were made on indeterminate, 19 (33.92%) on flakes, 8 (14.28%) on slabs, 2 (3.57%) on blocky, 2 (3.57%) on cobble and only 1 (1.78%) was made on heat spall. The next frequent tool type was cleaver with 21.66% from the total tool type, in which 23 (88.46%) were made from flakes and 3 (11.53%) on indeterminate. Biface comes under the next tool type category with 7.5% from the total large tool type and out of these 9 biface types, 5 (55.55%) of them were made on indeterminate and 4 (44.44%) on flakes. cleaver blank (7.5%) and axe blank (6.66%) are the other tool types, among 9 (7.5%) cleaver blanks, 9 (100%) of them were made on flakes and from the 8(6.66%) axe blanks, 6 (75%) were made on flakes, 1 (12.5) on slab and the other 1 (12.5) was made from indeterminate. Rest of the tool types like pushplane, assayed core, various biface and knives had the minimum counts. Of these tool types, pushplane were made on 2 (66.66%) flakes and 1 (33.33%) cobble type; assayed core were made on 1 indeterminate and 1 blocky; various biface were made on a slab and knives were made on 1 flake type.

Therefore, it can be inferred that the majority of the large cutting tools were made from flakes and slabs types (Figure 4.6.3) and those which had no or minimum information on the initial forms are flaked completely and were grouped as indeterminate. Hominins at this site preferred slab and flake as the initial form for manufacturing handaxe and cleavers, as the most frequent tool types.

Table 4.6.4. Frequency table of cortex types for large cutting tool types at Khyad.

Flaked Piece type	Blocky	Cobble	Slab	Flake	Heat spall	Indeterminate	Grand Total
Assayed Core	1(50)	0(0.0)	0(0.00)	0(0.00)	0(0.0)	1(50)	2(1.7)
Axe Blank	1(11.1)	0(0.0)	1(11.1)	6(66.6)	0(0.0)	1(11.1)	9(7.7)
Biface	0(0.0)	0(0.0)	0(0.0)	4(44.4)	0(0.0)	5(55.5)	9(7.7)
Cleaver	0(0.0)	0(0.0)	0(0.0)	23(88.5)	0(0.0)	3(11.5)	26(22.4)
Cleaver Blank	0(0.0)	0(0.0)	0(0.0)	9(100)	0(0.0)	0(0.0)	9(7.7)
Handaxe	2(3.6)	2(3.6)	8(14.3)	19(33.9)	1(1.8)	24(42.8)	56(48.3)
Knives	0(0.0)	0(0.0)	0(0.0)	1(100)	0(0.0)	0(0.0)	1(0.86)
Pushplane	0(0.0)	1(33.3)	0(0.0)	2(66.7)	0(0.0)	0(0.0)	3(2.6)
Various Biface	0(0.0)	0(0.0)	1(100)	0(0.0)	0(0.0)	0(0.0)	1(0.86)
Total	**4(3.4)**	**3(2.6)**	**10(8.6)**	**64(55.2)**	**1(0.86)**	**34(29.3)**	**116**

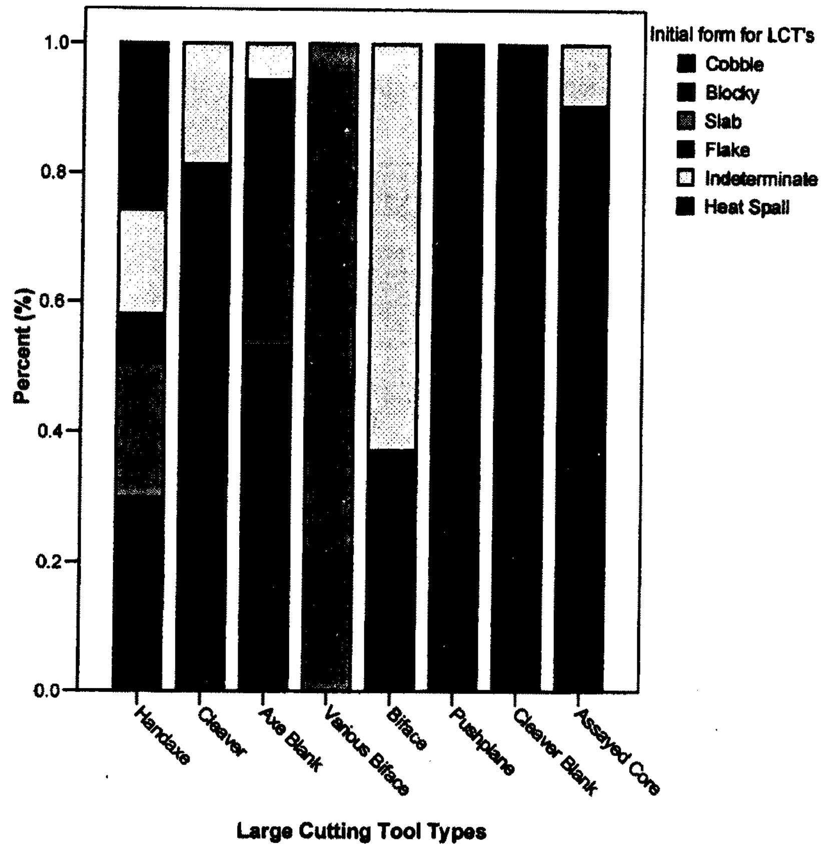

Figure 4.6.3. Stacked bar graph of large cutting tool types broken down by initial forms at Khyad.

Breakage pattern in large cutting tool types

This variable was recorded in order to see the breakage pattern in large cutting tools at this site and also to find out the error committed by the knappers at this site.

Among 116 large cutting tools, 16 were broken and of these, 8 of them were handaxes, 3 were cleavers, 4 were biface and 1 pushplane. Majority (93.75%) of large cutting tools had there tip broken. Many handaxes (7) were observed without the tip portion, next comes biface (4) and this biface was followed by cleaver (3) and pushplane (1) (Table 4.6.5). Whereas only one large cutting tool were noticed with the broken buttend and that is from handaxe. Broken tip are the result of end shock which is caused due to knapping error.

Table 4.6.5. Frequency table of breakage pattern for large cutting tool types at Khyad.

Breakage	Handaxe	Cleaver	Biface	Pushplane	Total
Tip is broken	7(87.5)	3(100)	4(100)	1(100)	15(93.75)
Buttend is broken	1(12.5)	0(0.0)	0(0.0)	0(0.0)	1(6.25)
Total	8	3	4	1	16

Tip shape of large cutting tool types

This non-metrical attribute is used as a proxy for shape variation within large cutting tools. It is applied to any large cutting tools irrespective of its 'typological' interpretation. The tip is here taken to be the upper third of the artifact. The shapes are as follows: - (1) Markedly convergent: Can have an acute or rounded tip (but must be visibly narrowing). Tip must be long and clearly tapering. (2) Markedly convergent but with a squared off tip. The tip is at roughly right angles to the long axis of the artifact. (3) Same as the above one (i.e., (2)) but with a clearly oblique shaped tip at an angle to the long axis of the artifact. (4) Markedly convergent with a generalized tip. 'Generalized' means that the tip doesn't fit into categories (1) – (3). (5) A right angled and broad tip on an artifact with divergent or parallel/sub-parallel sides at the cutting end of the tool. (6) Same as in (5), but with a wide tip at a markedly oblique angle to the long axis of the tool. (7) Wide with a very convex tip and without any break in the convexity.

Table 4.6.6. Frequency table of tip shape for large cutting tool types at Khyad.

Tip Shape	Handaxe	Cleaver	Axe Blank	Various Biface	Biface	Pushplane	Cleaver Blank	Assayed Core	Total
A type	26 (50.9)	0 (0.0)	6 (66.6)	0 (0.0)	3 (50)	0 (0.0)	0 (0.0)	1 (50)	36 (34.6)
B type	0 (0.0)	1 (4.3)	1 (11.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (1.9)
C type	3 (5.8)	0 (0.0)	0 (0.0)	0 (0.0)	1 (16.6)	0 (0.0)	0 (0.0)	1 (50)	5 (4.8)
D type	17 (33.3)	3 (13)	2 (22.2)	0 (0.0)	2 (33.3)	1 (33.3)	0 (0.0)	0 (0.0)	25 (24.03)
E type	0 (0.0)	18 (78.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (33.3)	9 (100)	0 (0.0)	28 (26.9)
F type	1 (1.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (33.3)	0 (0.0)	0 (0.0)	2 (1.9)
G type	4 (7.8)	0 (0.0)	0 (0.0)	1 (100)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5 (4.8)
Indeterminate	0 (0.0)	1 (4.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.96)
Total	**51**	**23**	**9**	**1**	**6**	**3**	**9**	**2**	**104**

Out of 116 large cutting tools, 104 (86.6%) had information on the tip shapes and from these, 36 (34.6%) of them had markedly convergent tip shape, 28 (26.9%) had right angled and broad tip, with divergent or parallel/sub-parallel sides, 25 (24.03%) had markedly convergent with a generalized tip, 5 (4.8%) had markedly convergent but with a squared off tip, 5 (4.8%) had wide with a very convex tip and without any break in the convexity, 2 (1.9%) had markedly convergent but with a squared off tip. 2 (1.9%) had right angled and broad tip, with divergent or parallel/sub-parallel sides, but with a wide tip at a markedly oblique angle to the long axis and 1 (0.96%) of the large cutting tools could not be grouped into any of the above mentioned groups and therefore it was placed into indeterminate group.

In the handaxe type the maximum number of tip shape was markedly convergent (26), followed by markedly convergent with a generalized tip (17), wide and convex tip (4), markedly convergent with a squared off tip (3) and right angled and broad tip with divergent or parallel/sub-parallel sides at the cutting end, but with a wide tip at a markedly oblique angle to the long axis of the tool (1). For axe blanks the most common tip shape is markedly convergent (6) and the next common tip shape is markedly convergent with a generalized tip (2). Markedly convergent with a squared off tip was the least type of tip shape found on the axe blank. Biface had two types of tip shape and they are markedly convergent tip (3) and markedly convergent with a generalized tip (2) and for assayed core also there were two types of tip shapes, namely markedly convergent tip (1) and markedly convergent with a generalized tip with oblique shaped tip (1).

Cleaver types had maximum (18) of right angled and broad tip with divergent or parallel/sub-parallel sides at the cutting end of the tool tip shape was used and 3 with markedly convergent with a generalized tip. Markedly convergent but with a squared off tip was the least tip shape of cleavers. Right angled and broad tip with divergent or parallel/sub-parallel sides at the bit was the major tip shape for cleaver blank which was noticed at this site.

From three pushplanes, 1 (33.3%) had markedly convergent with a generalized tip, another 1 (33.3%) had right angled and broad tip, with divergent or parallel/sub-parallel sides and the rest 1 (33.3%) had right angled and broad tip, with divergent or parallel/sub-parallel sides, but with a wide tip at a markedly oblique angle to the long axis. From Table 4.6.6., it can concluded that the most common tip

shape of handaxes was of markedly convergent with long and narrowing tip and for cleavers the most common tip shape was right angled and broad tip with divergent or parallel/sub-parallel sides at the cutting end of the tool.

Profile form for large cutting tool types

A profile form refers to the form of a large cutting tool in a profile. Profile form categories include straight, regular and irregular. From 116 large cutting tools, 115 had information on profile form in large cutting tools. From these 115, majority (60) of these large cutting tools had irregular profile form followed by 45 (39.1%) regular profile form and 10 (8.7%) had straight profile form. From this majority i.e., 26 (46.4%) of the handaxe had regular profile form followed by 22 (39.3%) of irregular and only 8 (14.3%) had straight profile form and with axe blank, all had irregular profile form.

Majority, 14 (56%) of cleavers had irregular profile form followed by 10 (40%) regular profile form were noticed on cleavers and only 1 cleaver had straight profile form. Cleaver also showed that maximum i.e., 6 (66.7%) of them had irregular profile form and the next common profile form was regular (3).

Most of the biface had irregular (7) profile form followed by regular (2) and straight (1). Various biface's profile form was regular and for pushplane, 2 (66.7%) pushplane had regular profile form and 1 (33.3%) had irregular profile form.

Table 4.6.7. Frequency table of profile form for large cutting tool types at Khyad.

Profile Form	Handaxe	Axe Blank	Cleaver	Cleaver Blank	Biface	Various Biface	Pushplane	Assayed Core	Total
Straight	8 (14.3)	0 (0.0)	1 (4)	0 (0.0)	1 (10)	0 (0.0)	0 (0.0)	0 (0.0)	10 (8.7)
Regular	26 (46.4)	0 (0.0)	10 (40)	3 (33.3)	2 (20)	1 (100)	2 (66.7)	1 (50)	45 (39.1)
Irregular	22 (39.3)	9 (100)	14 (56)	6 (66.7)	7 (70)	0 (0.0)	1 (33.3)	1 (50)	60 (52.2)
Total	**56**	**9**	**25**	**9**	**10**	**1**	**3**	**2**	**115**

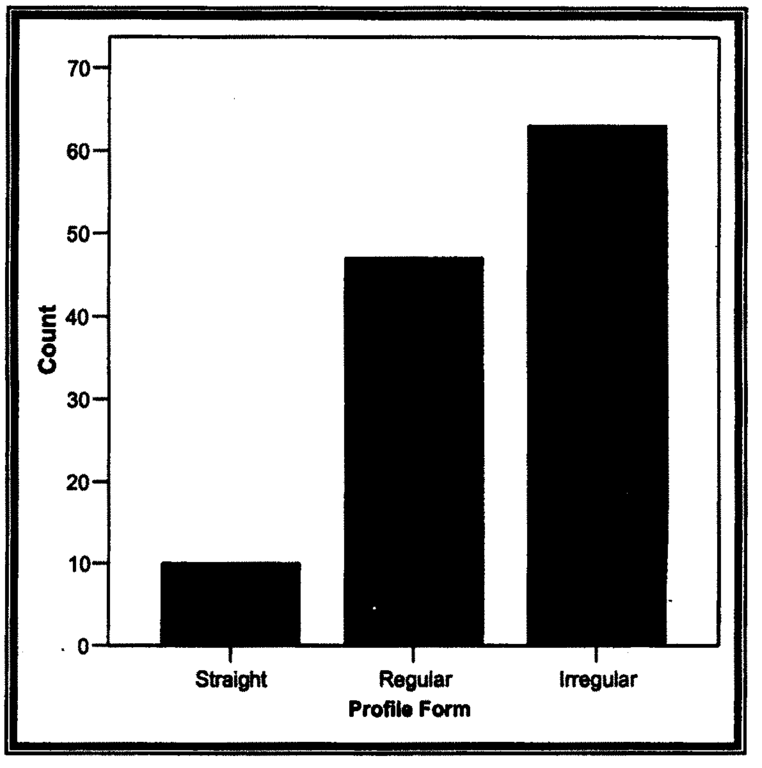

Figure 4.6.4. Bar graph of profile form for large cutting tool types at Khyad.

Cross section of large cutting tool types

This attribute is an indicative of the shape for large cutting tools and the categories are biconvex, lenticular, circular, high back, low back, triangle, sub-triangle, trapezoid, rhomboid, parallelogram, irregular, and polygon.

Table 4.6.8. Frequency table of cross section for large cutting tool types at Khyad.

Cross Section	Handaxe	Cleaver	Axe Blank	Various Biface	Biface	Pushplane	Cleaver Blank	Assayed Core	Total
Biconvex	28 (65.1)	13 (52)	2 (22.2)	0 (0.0)	9 (90)	1 (33.3)	5 (55.5)	0 (0.0)	58 (56.8)
Lenticular	6 (13.9)	5 (20)	1 (11.1)	0 (0.0)	0 (0.0)	0 (0.0)	1 (11.1)	0 (0.0)	13 (12.7)
Sub-Triangular	2 (4.6)	1 (4)	1 (11.1)	0 (0.0)	0 (0.0)	0 (0.0)	1 (11.1)	0 (0.0)	5 (4.9)
Parallelogram	0 (0.0)	1 (4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (11.1)	1 (50)	3 (2.9)
Irregular Quadrilateral	2 (4.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (50)	3 (2.9)
Low Back	1 (2.3)	0 (0.0)	0 (0.0)	1 (100)	0 (0.0)	0 (0.0)	1 (11.1)	0 (0.0)	3 (2.9)
High Back	4 (9.3)	4 (16)	5 (55.5)	0 (0.0)	1 (10)	2 (66.6)	0 (0.0)	0 (0.0)	16 (15.7)
Triangular	0 (0.0)	1 (4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.98)
Total	**43**	**25**	**9**	**1**	**10**	**3**	**9**	**2**	**102**

Out of 116 large cutting tools, 102 of them contain the information on the large cutting tools cross section. Among the 102, 58 (56.8%) had biconvex cross section followed by 16 (15.7%) high back, 13 (12.7%) lenticular, 5 (4.9%) sub-triangular, 3 (2.9%) parallelogram, 3 (2.9%) irregular quadrilateral, 3 (2.9%) low back and 1 (0.98%) triangular. Biconvex is the major cross section types in the handaxe with 65.1%, cleaver with 52%, biface with 90% and cleaver blank with 55.5% (Table 4.6.8). Whereas the other two tool types namely axe blank with 55.5% and pushplane with 66.6% have high back cross section with maximum percentage and remaining tool types like various biface having low back cross section and assayed core which have cross sections like parallelogram and irregular quadrilateral.

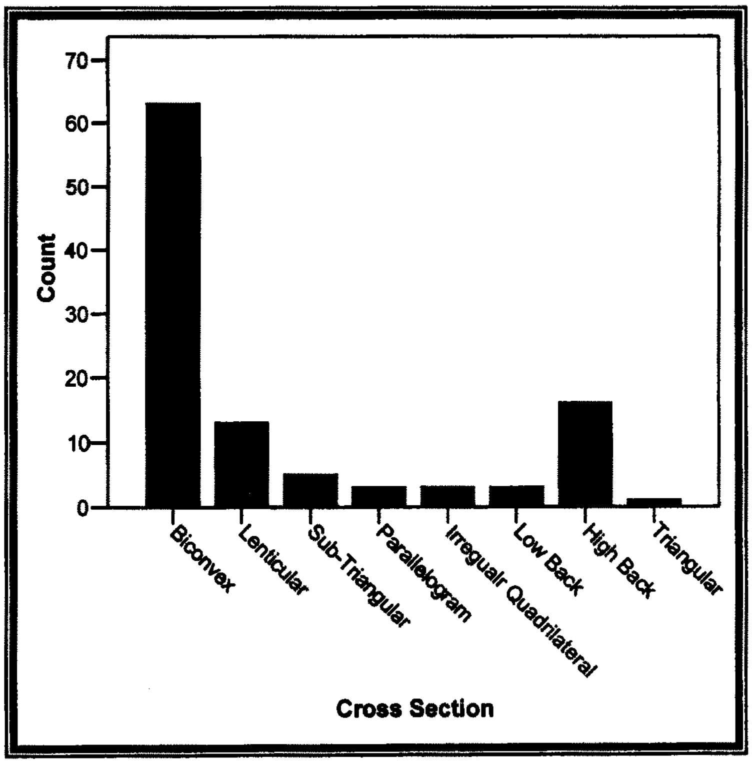

Figure 4.6.5. Bar graph of cross section for large cutting tool types at Khyad.

4.7. General metrical measurements for large cutting tool types

Many general attributes were selected for recorded the large cutting tools in order to see the differences within each types and between the types that were found. Table 4.7.1., provides the mean, minimum, maximum and standard deviation of maximum dimension, maximum width, thickness and weight for large cutting tool types and partial correlation test is also conducted for the large cutting tool types.

Box plots are used to visually compare large cutting tool types by depicting central tendency and dispersion. They show the total range of the batch, the median of the population (shown as the central-most line in the box), the inter-quartile range (shown by the box), adjacent values (shown by the whiskers), outliers (shown as circles), and extreme values (shown as asterixis). The inter-quartile range, or *midspread*, represents the central half (50%) of the numbers in the batch, while the whiskers include all values less than 1.5 times the midspread (that is the central 75% of numbers). Extreme values are all those more than three times the length of the midspread from the edge of inner quartiles. Outliers are all values between the whiskers and extremes. Histograms were also used to explain the mode and range of population.

In this section quantitative and qualitative aspects of size and shape differences between assemblage and raw material type will be explained. The 2 and 3rd Step of Method of Residual of Isaac which explains the economy of flaking, transport, tool maintenance, and functional aspects of large cutting tools will also be discussed.

Large cutting tools were classified as assayed core, handaxes, cleaver, axe blank, cleaver blank, biface and pushplane. Handaxe (56) were the maximum large cutting tools which were collected from this site and this was followed by cleavers (25), biface (10), axe blank (9), claver blank (9), pushplane (3) and assayed core (2) was the least in count. Assayed core and pushplane are ignored in the statistical analysis because of small sample size (>5).

Large cutting tools from Khyad vary considerably in size and shape, as explained by the by standard deviation of variation for measurements and for ratios (Table 4.7.1). Large cutting tool vary in length (95.04 -212.7 mm), width (64.13-139.89 mm), thickness (25.97-76.46 mm) and weight (45.8-1820 mm). Table 4.7.1 and Figure 4.7.1 to 4.7.4., provides a box plot of maximum dimension for all large cutting tools. Handaxe (212.7 mm) have greater maximum dimensions than all other large cutting tools. Cleavers (190.78 mm) are the second largest large cutting tools and are followed by axe blanks (188.78 mm), assayed core (181.07 mm), pushplane (172.97 mm), cleaver blank (169.79 mm) and biface (151.13 mm) and various biface (133.51 mm) which are the smallest among all the large cutting tools.

Basic descriptive statistics for large cutting tools for individual assemblage are shown in Table 4.7.1. The table provides mean, minimum, maximum, standard deviation and coefficient of variation for measurements for length, width, thickness and weight. In statistics standard deviation is used to measure the variation within a given population. The above table shows variations within maximum dimension, maximum width, thickness and weight of large cutting tools. The value for standard deviation of the maximum dimension is higher in handaxe (27.91) and cleaver (22.16) than the other types of large cutting tools. According to the maximum width, thickness and weight of large cutting tools cleaver blank and axe blank have the highest standard deviation values revealing the variation within these types. Biface have the lowest standard deviation values indicating very less variation within in these types of large cutting tools. From the Table 4.7.1., large cutting tool's linear measurements differ considerably.

Large cutting tools length varies considerably (CV=0.15) between large cutting tools with the longest large cutting tools. Longest large cutting tools are handaxe and shortest are biface (124.57±15.52mm). Standard deviation and coefficient of variation indicates significant variability in large cutting tool types. Handaxe tend to be longer than any other large cutting tools.

Large cutting tools breadth (maximum width) varies considerably (CV=0.13) between large cutting tool. Widest large cutting tools are cleaver blank (98.31±14.61 mm) and the most narrow large cutting tool is biface (75.51±6.99 mm). Thickness varies considerably (CV=0.27) between large cutting tool. The thickest large cutting tools from Khyad is axe blank (46.19±12.91 mm) and the thinnest is biface (40.56±8.71mm). Weight also varies considerably (CV=0.483) between large cutting tools at Khyad. Heaviest large cutting tool are the axe blanks (703.89±457.73 gms) and the lights are biface (393±140.66 gms).

Length versus maximum width has an isometric relationship within Khyad large cutting tools (Figure 4.7.7). Figure 4.7.7., shows that as the length increases maximum width also increases. Maximum width versus thickness also shows an isometric relationship within the large cutting tools (Figure 4.7.8) and this isometric relation shows that, as the maximum width increases thickness also increases. The allometry of large cutting tools is best expressed in Length versus shape index (B/L).

Breadth/Length ratio provides a measure of narrow versus broad large cutting tools relative to length (Roe 1964, 1968). Figure 4.7.5., is a plot of mean length versus mean breadth/length for large cutting tools from Khyad. Large cutting tool with higher mean lengths tend to be proportionally narrower, while large cutting tool with lower mean length are proportionally broader. Large cutting tool form-defining ratios (B/L, and T/B, T1/T3, T1/L, B1/B3 and CEL/B) in assemblages are also variable but the breadth/length ratio is the least variables of all ratios (CV=0.17). Thickness/Breadth ratios are highly variables among the large cutting tools. Biface (0.53), axe blank (0.53) and cleaver (0.46) are the thickest large cutting tools, while handaxe (0.5) is the thinnest large cutting tool from Khyad. Large cutting tool's morphological variability is high, with coefficients of variation that are often >0.44.

Table 4.7.1. Mean, minimum, maximum, standard deviation and coefficient of variation of general metrical measurements for the large cutting tools from Khyad.

Variable	Type	Mean	Minimum	Maximum	Std. Deviation	CV
Length (Maximum Dimension)	Axe Blank	149.48	125.57	188.78	21.8	0.15
	Handaxe	138.64	97.65	212.7	27.91	0.20
	Cleaver Blank	139.17	104.54	169.79	18.54	0.13
	Cleaver	135.32	95.04	190.78	22.16	0.16
	Biface	124.57	104.54	151.13	15.52	0.12
	Total	137.39	95.04	212.70	24.64	0.18
Width	Axe Blank	86.47	67.5	102.93	13.26	0.15
	Handaxe	84.53	57.58	118.63	12.38	0.15
	Cleaver Blank	98.31	79.66	125.93	14.61	0.15
	Cleaver	88.53	69.06	109.42	10.2	0.12
	Biface	75.51	64.13	84.47	6.99	0.09
	Total	86.33	57.58	139.89	13.46	0.16
Thickness	Axe Blank	46.19	30.42	72.7	12.91	0.28
	Handaxe	42.67	27.17	76.46	11.74	0.28
	Cleaver Blank	42.98	31.98	74.95	14.71	0.34
	Cleaver	42.47	28.1	76.31	11.31	0.27
	Biface	40.56	25.97	53.69	8.71	0.21
	Total	43.08	25.97	76.46	11.50	0.27
Weight	Axe Blank	703.89	388	1820	457.73	0.65
	Handaxe	505.46	45.8	1607	281.41	0.56
	Cleaver Blank	569.33	348	1070	214.53	0.38
	Cleaver	561.28	277	1560	266.3	0.47
	Biface	393	203	632	140.66	0.36
	Total	540.42	45.80	1820.00	294.93	0.55

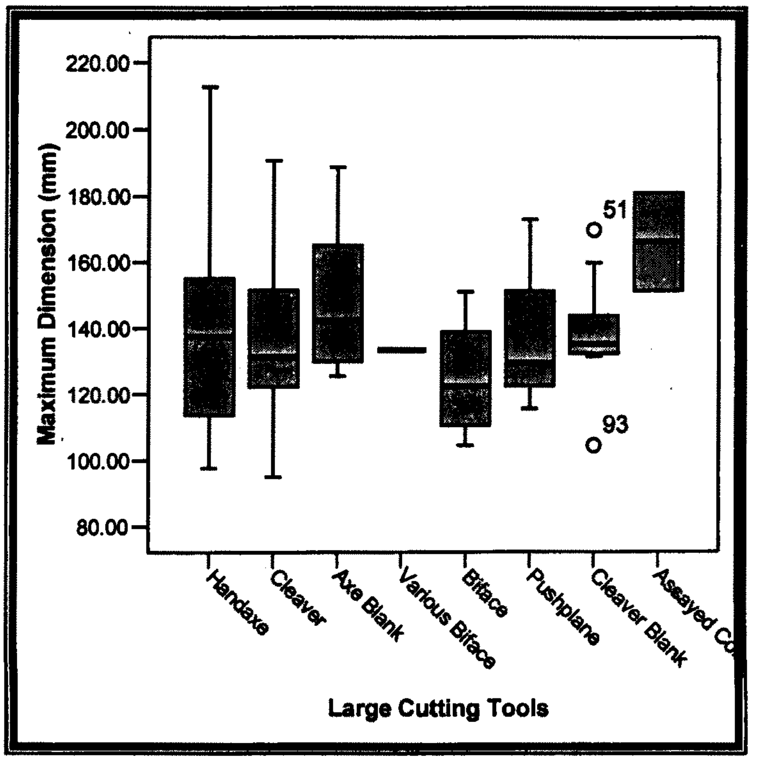

Figure 4.7.1. A box plot for maximum dimension of large cutting tool types from Khyad.

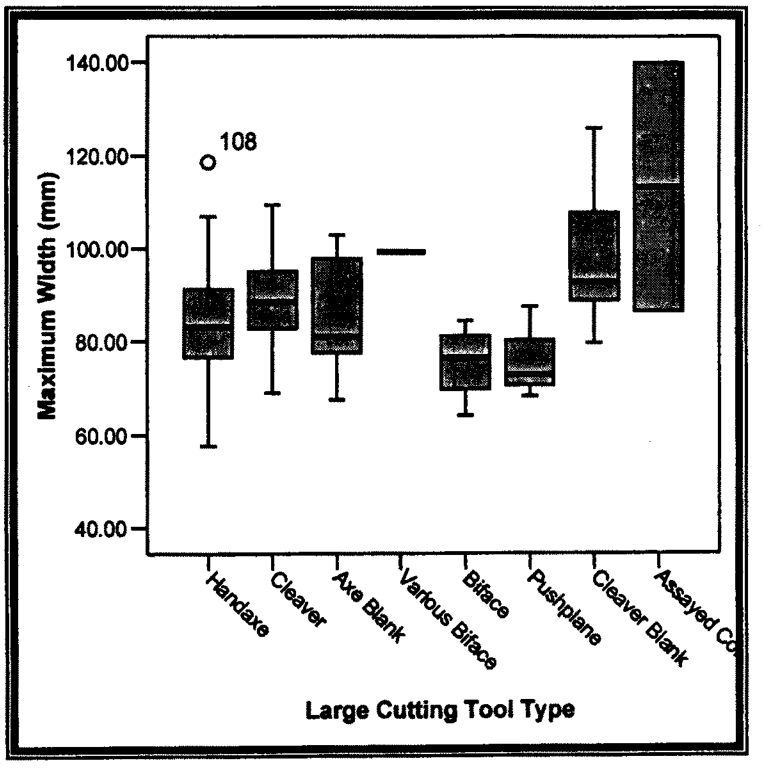

Figure 4.7.2. A box plot for maximum width of large cutting tool types from Khyad.

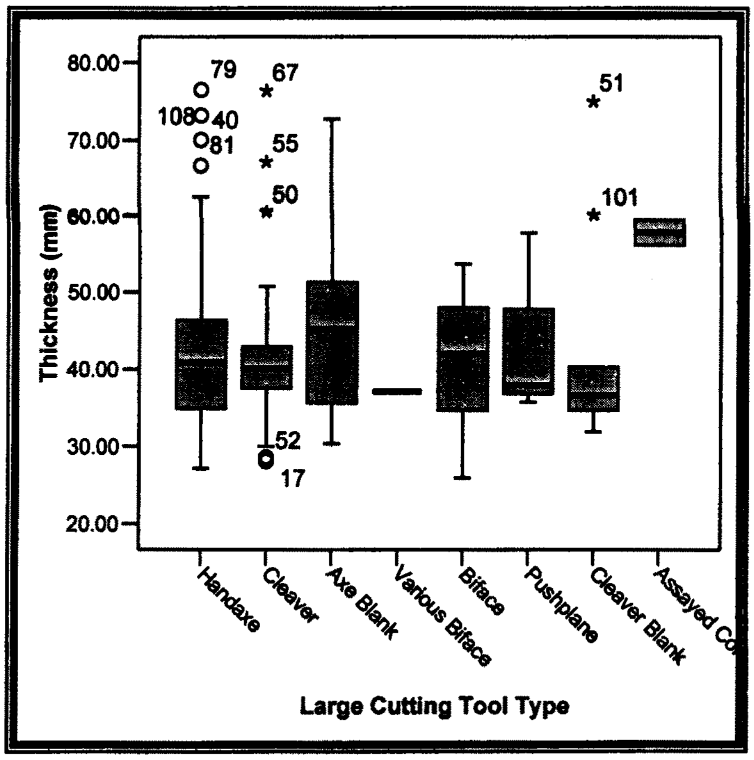

Figure 4.7.3. A box plot for thickness of large cutting tool types from Khyad.

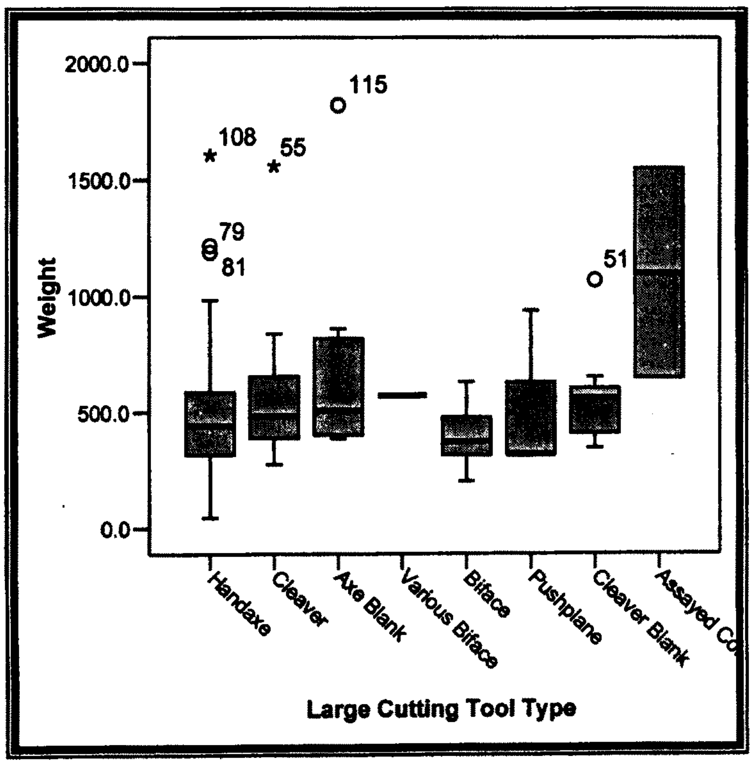

Figure 4.7.4. A box plot for maximum dimension of large cutting tool types from Khyad.

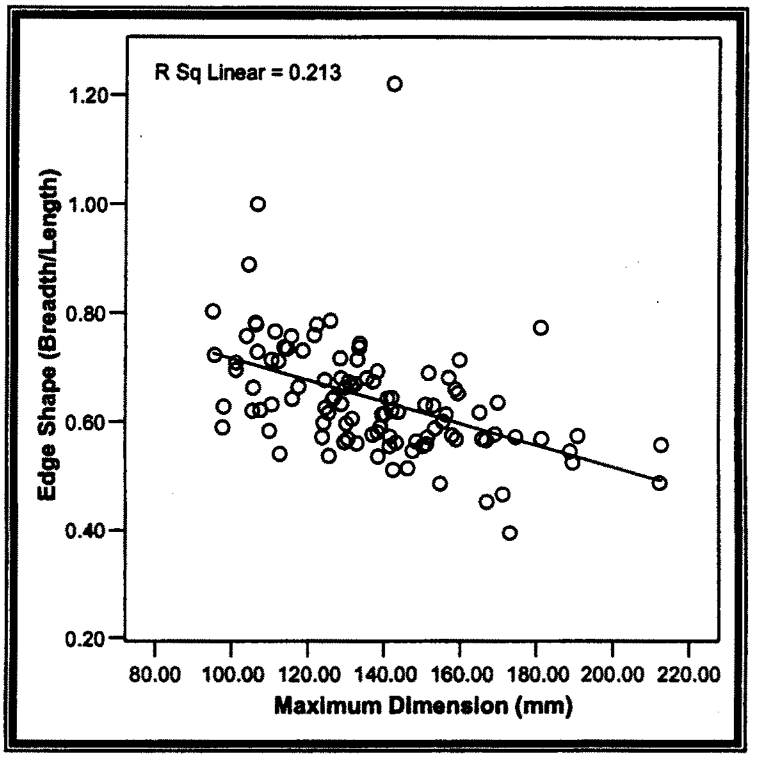

Figure 4.7.5. A scatter plot with linear regression line for edge shape (length shape index (B/L) for Khyad large cutting tools shows shorter large cutting tools are broader, while longer large cutting tools are narrower. A simple linear regression was also generated with R Sq Linear=0.213

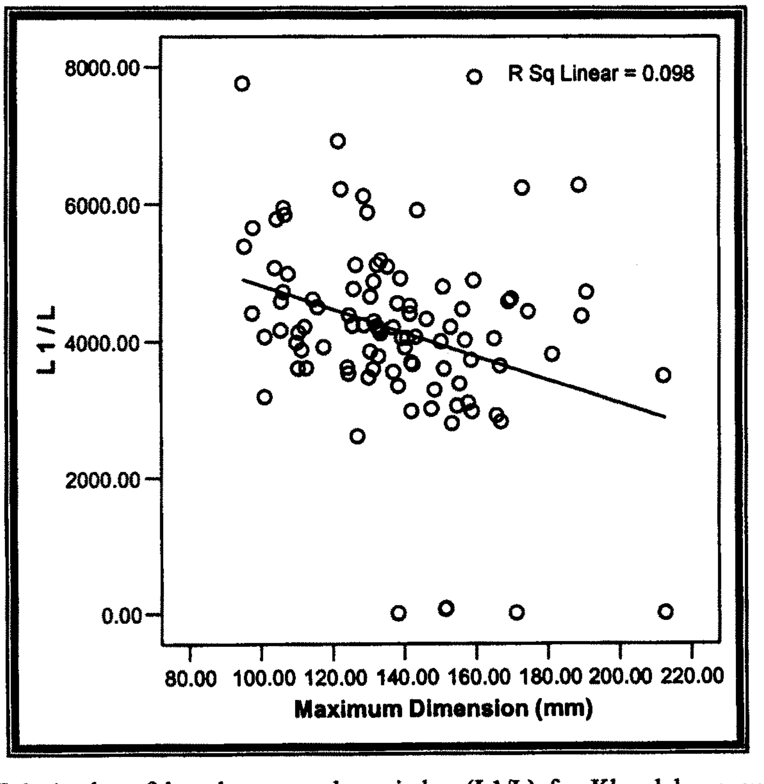

Figure 4.7.6. A plot of length versus shape index (L1/L) for Khyad large cutting tools shows shorter large cutting tools are broader, while longer large cutting tools are narrower. A simple linear regression was also generated with R Sq Linear=0.098

From Figure 4.7.5., it can be inferred that, as the mean length increases, the shape index (B/L) decreases tends to be proportionally narrower or longer large cutting tools. Same thing can be explained by plotting length versus L1/L (Figure 4.7.6). As Roe (1964, 1968) has suggested that large cutting tools which have <0.350 L1/L ratio fall into pointed large cutting tools and large cutting tools which have >0.350 to <0.550 falls into broader large cutting tools.

Correlation between general metrical measurements of large cutting tools.

Table 4.7.2., is a bivariate correlation which focuses on relationship between pair of variables for large cutting tools. From the above table it is clear that maximum dimension, maximum width, thickness and weight of the large cutting tools have a significant correlation at 0.01 level and the positive Pearson Correlation indicates that, as the maximum dimension value increases, other variables (maximum width, thickness and weight) value also increases. Correlation is significant at 0.05 levels with negative values of Pearson Correlation for total scar count and index of invasiveness for large cutting tools. When the maximum dimension, maximum width, thickness and weight are compared with total scar count, it gave a negative Pearson Correlation values which indicates that the total scar count increases as the maximum dimension, maximum width, thickness and weight decreases and when the index of invasiveness is compared with other variables, it did not show any significant values except when it was compared with total scar count. The Pearson Correlation value is in positive with significant correlation at 0.01 levels when the comparison was made with index of invasiveness and total scar count; this indicates that, as the index of invasive value increases the total number of scar count increased.

From the above table and from its description it can be summarized that the bivariate correlation test revealed interesting aspects of the large cutting tools and they are:

- Linear measurements for shape/morphology and size of large cutting tools like maximum dimension, maximum width, thickness and weight showed an increase in the value when it was compared within the group itself along with the positive Pearson Correlation value.

- Flake scar count and index of invasiveness of large cutting tools showed an increase in value when it was compared within themselves with a positive Pearson Correlation value. When these two variables were compared with linear measurements with the total flake scar count and index of invasiveness showed a negative value of Pearson Correlation, indicating the result of reduction on the shape/morphology and size of the large cutting tools.

Table 4.7.2. Bivariate correlation test result within and between large cutting tools general linear attributes. All general linear attributes which are significant at 0.01 level are in blue colour and 0.05 level in red colour. The attribute which are significant in 2-tailed level are marked in bold.

Correlations							
Variable		**Maximum Dimension**	**Maximum Width**	**Thickness**	**Weight**	**Total Scar Count**	**Index**
Maximum Dimension	Pearson Correlation	1	0.654	0.566	0.849	-0.153	-0.012
	Sig. (2-tailed)		0.000	0.000	0.000	0.151	0.899
	N	120	120	120	120	89	120
Maximum Width	Pearson Correlation	0.654	1	0.416	0.721	-0.218	-0.168
	Sig. (2-tailed)	0.000		0.000	0.000	0.041	0.066
	N	120	120	120	120	89	120
Thickness	Pearson Correlation	0.566	0.416	1	0.706	-0.249	-0.106
	Sig. (2-tailed)	0.000	0.000		0.000	0.019	0.249
	N	120	120	120	120	89	120
Weight	Pearson Correlation	0.849	0.721	0.706	1	-0.265	-0.104
	Sig. (2-tailed)	0.000	0.000	0.000		0.012	0.258
	N	120	120	120	120	89	120
Total Scar Count	Pearson Correlation	-0.153	-0.218	-0.249	-0.265	1	0.706
	Sig. (2-tailed)	0.151	0.041	0.019	0.012		0.000
	N	89	89	89	89	89	89
Index of Invasiveness	Pearson Correlation	-0.012	-0.168	-0.106	-0.104	0.706	1
	Sig. (2-tailed)	0.899	0.066	0.249	0.258	0.000	
	N	120	120	120	120	89	120

Figure 4.7.7 and 4.7.8., shows that as the maximum dimension increases the maximum width, thickness and weight also increases. Maximum dimension versus maximum width has an isometric relationship within Khyad large cutting tools.

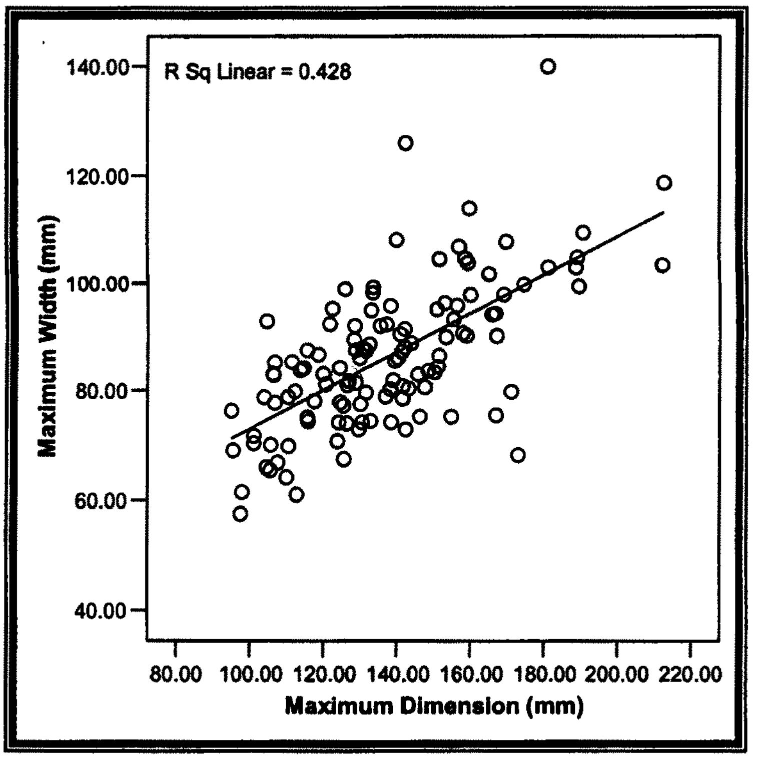

Figure 4.7.7. A plot of length versus breadth for Khyad large cutting tool types. The relationship between length and breadth is reasonably isometric. A simple linear regression was also generated with R Sq Linear=0.428

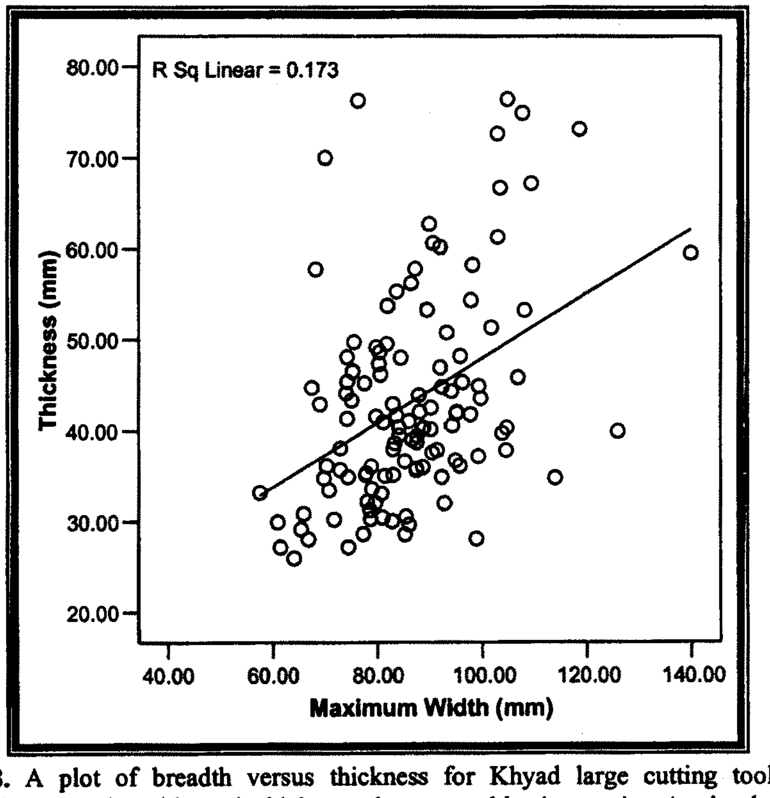

Figure 4.7.8. A plot of breadth versus thickness for Khyad large cutting tools. The relationship between breadth and thickness is reasonably isometric. A simple linear regression was also generated with R Sq Linear=0.173

4.8. Additional metrical measurements for size and shape of large cutting tool types

The additional attributes for shape/morphological measures of large cutting tools were taken. The above table (Table 4.8.1) provides the mean, minimum, standard deviation and coefficient of variation of tip width (B1), mid width (B2), base width (B3), tip thickness (T1), mid thickness (T2), base thickness (T3), base length and tip length of the large cutting tools. Cleaver Blank (114 mm) has a higher tip width (B1) value than all other large cutting tools. Cleavers (104.6 mm) has the second largest tip width (B1) value, followed by axe blanks (81.7mm) and handaxe (78.8 mm). The maximum mid width (B2) value for the cleaver (109.4 mm) as well as cleaver blank (107.8 mm) are higher than the following tool types like hand axe (113.9 mm) and axe blank (102.9 mm). In the maximum base width (B3) value, both hand axe (96.8 mm) and axe blank (96.6 mm) are dominating with the maximum value comparing with the other two tool types, following next, cleaver (67.6 mm) and cleaver blank (61.9 mm). Axe blank (243.3 mm) has the highest value in the maximum tip thickness (T1) whereas handaxe (42.7 mm), cleaver blank (34.9 mm) and cleaver (34.4 mm) has the lowest value for the tip thickness. Maximum mid thickness (T2) value of the cleaver blank (75 mm) is the highest than the handaxe (73.2 mm), axe blank (71.8 mm) and cleaver blank (67.2 mm). Axe blank (72.7 mm) has the highest maximum base thickness value followed by handaxe (62.7 mm), cleaver (60.6 mm) and cleaver blank (60.2 mm). The maximum base length value of cleaver blank (125.4 mm) is the highest than axe blank (118.4 mm) and cleaver (109.9 mm), while the handaxe (90.2 mm) has the lowest maximum base length value. Regarding the maximum tip length value, handaxe has the highest value (138.1 mm) than cleaver (109 mm), axe blank (98.3 mm) and cleaver blank (91.3 mm).

The above table shows variations within tip width (B1), mid width (B2), base width (B3), tip thickness (T1), mid thickness (T2), base thickness (T3), base length and tip length of the large cutting tools. The value for standard deviation of the tip width (14.2), mid thickness (51.1) and base length (22.9) is higher in cleaver blank, explains the variation in cleaver blank's tip width, mid thickness and base length. The standard deviation of handaxe is more in the mid width (12.3) and base width (12.8) value, indicating the variation within the mid width and base width value of

handaxe. The higher value of the tip thickness (73.2) and base thickness (14.8) of axe blank in the standard deviation shows the variation within the tip thickness and base thickness. The standard deviation of cleaver's tip length (25.4) is higher than other types.

Table 4.8.1. Mean, minimum, maximum, standard deviation and coefficient of variation for additional metrical measurements for large cutting tool types from Khyad.

Variable	Type	Mean	Minimum	Maximum	Std. Deviation	CV
Tip Width	Axe Blank	52.9	39.7	81.7	12.8	0.24
	Handaxe	52.7	26.8	78.8	12.6	0.24
	Biface	53.6	47.25	65.45	6.5	0.12
	Cleaver Blank	84.2	69.1	114.0	14.2	0.17
	Cleaver	79.1	43.4	104.6	13.5	0.17
Mid Width	Axe Blank	86.3	67.5	102.9	13.4	0.16
	Handaxe	81.7	54.5	113.9	12.3	0.15
	Biface	76.5	64.1	84.5	7.9	0.10
	Cleaver Blank	92.0	79.7	107.8	8.4	0.09
	Cleaver	87.2	69.1	109.4	10.0	0.11
Base Width	Axe Blank	78.0	61.4	96.6	11.2	0.14
	Handaxe	73.5	48.7	96.8	12.8	0.17
	Biface	69.4	64.1	80.7	6.1	0.09
	Cleaver Blank	80.1	67.6	92.9	8.9	0.11
	Cleaver	75.1	61.9	91.6	8.5	0.11
Tip Thickness	Axe Blank	50.6	14.5	243.3	73.2	1.45
	Handaxe	21.5	13.8	42.7	6.2	0.29
	Biface	21.2	15.2	25	3.7	0.17
	Cleaver Blank	22.1	17.9	34.9	5.6	0.25
	Cleaver	20.9	15.1	34.4	4.4	0.21
Mid Thickness	Axe Blank	43.8	25.6	71.8	13.1	0.30
	Handaxe	39.4	27.2	73.2	9.5	0.24
	Biface	39.5	26	48.6	9	0.23
	Cleaver Blank	39.8	23.9	75.0	15.1	0.38
	Cleaver	40.5	27.7	67.2	8.4	0.21
Base Thickness	Axe Blank	42.5	27.5	72.7	14.8	0.35
	Handaxe	34.6	18.7	62.7	9.9	0.29
	Biface	34.3	21.9	53.7	10.9	0.32
	Cleaver Blank	34.4	24.8	60.2	11.0	0.32
	Cleaver	36.4	28.1	60.6	8.3	0.23
Base Length (For LCT's)	Axe Blank	68.3	45.3	118.4	21.4	0.31
	Handaxe	55.2	32.2	90.2	12.7	0.23
	Biface	54.2	43.8	68.4	8.9	0.16
	Cleaver Blank	74.8	55.5	125.4	22.9	0.31
	Cleaver	63.7	42.3	109.9	17.8	0.28
Tip Length	Axe Blank	81.5	61.7	98.3	11.8	0.14
	Handaxe	82.1	42.5	138.1	22.8	0.28
	Biface	75.5	64.8	96.7	12.6	0.17
	Cleaver Blank	64.0	34.4	91.3	18.3	0.29
	Cleaver	71.0	21.3	109.0	25.4	0.36

Additional measurements which were taken for large cutting tools are then used to generate indices to define the shape and refinement of large cutting tools. Table 4.8.2., provides the mean, minimum and standard deviation of B1/B3 (Shape Index), T/B (Refinement Index), B/L (Shape Index) and CEL/B (For Cleavers).

Large cutting tool type's index ratios (breadth1/ breadth3, breadth/length, thickness/breadth and thickness1/thickness3) are quite variable. Breadth1/breadth3 ratios have considerable variability among handaxe type (CV=24) than other tool types. High mean value of B1/B3 ratio for handaxe, indicates that handaxes are the shorter than other types. When refinement is taken into account, axe blank have a high mean value (1.44) with high coefficient of variation value (CV=1.74). High mean value and high coefficient of variation value indicates that the axe blanks are the thinnest with more variation in them. Mean thickness/ breadth index ratio for axe blank and biface are higher than others indicating that these two types are the thinnest among large cutting tools, whereas cleaver blank shoe much variation (CV=0.32) in the thickness ratio. High breadth/length index ration for cleaver blank indicates that they are more elongated than others and high coefficient of variation indicates higher variability in the same types.

Table 4.8.2. Mean, standard deviation and coefficient of variation for shape defining index ratio for large cutting tool types from Khyad.

Index Ratio	Type	Mean	Std. Deviation	CV
B1/B3 (Shape Index by Roe)	Handaxe	0.72	0.17	0.24
	Axe Blank	0.68	0.12	0.18
	Biface	0.77	0.08	0.10
	Cleaver	1.07	0.21	0.20
	Cleaver Blank	1.06	0.19	0.18
T1/T3 (Refinement index)	Handaxe	0.64	0.18	0.28
	Axe Blank	1.44	2.51	1.74
	Biface	0.65	0.16	0.25
	Cleaver	0.59	0.12	0.20
	Cleaver Blank	0.68	0.21	0.31
T / B (Refinement index)	Handaxe	0.5	0.09	0.18
	Axe Blank	0.53	0.11	0.21
	Biface	0.53	0.08	0.15
	Cleaver	0.46	0.1	0.22
	Cleaver Blank	0.44	0.14	0.32
B / L (Shape Index byRoe)	Handaxe	0.62	0.08	0.13
	Axe Blank	0.58	0.04	0.07
	Biface	0.59	0.03	0.05
	Cleaver	0.67	0.08	0.12
	Cleaver Blank	0.75	0.2	0.27

Table 4.8.3., is a bivariate correlation which focuses on relationship between pair of variables for large cutting tools. Table 4.8.3., clearly shows the relation between B/L (Shape Index), T/B (Refinement Index) and tip length and index of invasiveness. When shape index (B/L) is compared with refinement index (T/B), tip length and index of invasiveness, the correlation for these values are significant at 0.01level (2-tailed) with negative values of Pearson Correlation. Bivariate correlation of shape index (B/L) with refinement index (T/B) gave a negative Pearson's Correlation value and this negative value shows that as the shape index decreases the refinement index increases explaining pointed large cutting tools are more refined than the broader large cutting tools. The negative Pearson's Correlation value for the combination of shape index and tip length and index of invasiveness indicates that as the shape index decreases the tip length and index of invasiveness increases. This explains that pointed large cutting tools have high tip length and high index of invasiveness. When refinement index (T/B) was compared with tip length it gave a significant value at 0.01level (2-talied) with negative Pearson Correlation value, this points out that the fact that higher tip length has low refinement index.

Thus it indicates that as reduction increases pointed large cutting tools become broader and thinner.

Table 4.8.3. Bivariate correlation test result within and between large cutting tools shape defining index ratio. The attribute which are significant in 2-tailed level are marked in bold.

Variable		**T / B**	**B / L**	**Tip Length**	**Index**
T / B	Pearson Correlation	1	**-0.523**	**0.400**	0.013
	Sig. (2-tailed)		**0.000**	**0.000**	0.886
	N	120	108	96	120
B / L	Pearson Correlation	**-0.523**	1	**-0.633**	**-0.269**
	Sig. (2-tailed)	**0.000**		**0.000**	**0.005**
	N	108	108	96	108
Tip Length	Pearson Correlation	**0.400**	**-0.633**	1	0.072
	Sig. (2-tailed)	**0.000**	**0.000**		0.487
	N	96	96	96	96
Index	Pearson Correlation	0.013	**-0.269**	0.072	1
	Sig. (2-tailed)	0.886	**0.005**	0.487	
	N	120	108	96	120

4.9. Differentiating large cutting tool types

A discriminant function analysis was conducted using all general and additional measurements for shape/morphological measures of large cutting tool types from Khyad, in order to differentiate the large cutting tool types. Table 4.9.1. to 4.9.3. and Figure 4.9.1., provides the information on two centroidal groups which were obtained during comparisons made among maximum dimension, maximum width, thickness, tip width, mid width, base width, tip thickness, mid thickness; base thickness, base length, tip length and tip shape of large cutting tool types and it is also clear from **Table** 4.9.1., which shows that 7 functions were obtained and with these 7 functions were used to obtain 7 different eigenvalues with seven different percentage of variances, with 1.974 eigenvalue for the first function having 48.2% of variance; 1.240 eigenvalue with 30.3% variance for the second function, 0.380 eigenvalue with 9.3%variance for the third, 0.246 eigenvalue with 6%variance for the fourth, 0.224 eigenvalue with 5.5%variance for the fifth, 0.029 eigenvalue with 0.7%variance for the sixth and 0.002 eigenvalue with 0.057% variance for the seventh function and Wilk's Lambda for function 1 through seventh functions is .000 having significant value.

Table 4.9.1. Obtaining eigenvalues with the help of seven functions for differentiating large cutting tool types from Khyad.

Eigenvalues				
Function	**Eigenvalue**	**% of Variance**	**Cumulative %**	**Canonical Correlation**
1	1.974	48.2	48.2	0.815
2	1.240	30.3	78.5	0.744
3	0.380	9.3	87.8	0.525
4	0.246	6.0	93.8	0.444
5	0.224	5.5	99.2	0.428
6	0.029	0.7	99.9	0.167
7	0.002	0.057	100	0.048

A structure matrix correlation test was obtained with the help of these three functions of variables for large cutting tool types. This structure matrix which was obtained to show the correlation for each variables that were chosen for this analysis are shown in Table 4.9.2., also gives further information about the significant correlation in seven functions like, the function 1 is shown with significant result in tip width and tip shape, function 2 has no significant differences, function 3 has significant results for the mid thickness, base thickness and thickness, function 4 has significant results for tip thickness, mid width and maximum width, function 5 have significant results for weight, function 6 have significant results for maximum dimension and base width and the last i.e., function 7 have no significant results.

Table 4.9.2. Discriminant function structure matrix of different variables for seven functions, using large cutting tool types from Khyad.

Structure Matrix							
	Function						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Tip Width (B1)	0.690	-0.178	-0.314	0.451	0.158	0.013	-0.154
Tip Shape	0.487	-0.014	-0.481	-0.035	0.382	-0.112	0.400
Mid Thickness	0.005	-0.160	0.396	0.135	0.249	0.210	-0.175
Base Thickness (Th3)	0.012	0.002	0.371	0.277	0.365	0.196	0.187
Thickness	0.020	-0.138	0.288	0.149	0.198	0.268	-0.068
Tip Thickness (Th1)	-0.088	0.070	0.240	0.651	0.152	0.248	-0.283
Mid Width	0.127	-0.093	-0.333	0.485	0.190	0.354	-0.004
Maximum Width	0.084	-0.330	-0.293	0.425	0.272	0.417	-0.035
Weight	0.030	-0.197	0.304	0.366	0.409	0.279	0.034
Maximum Dimension	-0.039	-0.097	0.268	0.171	0.276	0.651	-0.113
Base Width (B3)	-0.004	-0.371	0.026	0.430	-0.073	0.508	0.317

With the help of these three eigenvalues, seven functions were obtained; when these seven functions were compared within the variables of large cutting tool types which were selected for this analysis gave a significant result for obtaining group centroidal values (Table 4.9.3)., with positive and negative values. Table 4.9.3., it clearly shows that three large cutting tool types- handaxes, axe blanks, various biface, biface and assayed core which fall in first group having negative values and cleavers, cleaver blanks and pushplane in the second group having positive centroidal value. Figure 4.9.1., also clearly shows that the two groups (the first group consists of handaxes, axe blanks, various biface, biface and assayed core, and the second group consisted of cleavers, cleaver blanks and pushplane) from Khyad are totally different from each other.

Table 4.9.3. Seven functions of large cutting tool types for obtaining group centroidal values.

Functions at Group Centroids							
Large Cutting Tool Type	**Function**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Handaxe	-0.863	0.128	-0.137	-0.271	-0.059	0.051	0.011
Cleaver	1.875	-0.084	-0.030	0.106	0.029	-0.116	0.046
Axe Blank	-1.315	0.826	0.652	1.262	0.142	0.043	0.003
Various Biface	-0.740	1.768	-2.906	0.192	3.407	-0.414	-0.128
Biface	-0.225	0.470	0.580	-0.242	-0.598	-0.423	-0.109
Pushplane	3.241	1.770	3.986	-1.694	2.116	0.440	-0.067
Cleaver Blank	2.003	-0.562	-0.545	0.304	-0.293	0.297	-0.091
Assayed Core	-1.734	-6.915	0.725	0.198	0.725	-0.118	-0.017

In order to differentiate within large cutting tool types, a discriminant function analysis was conducted using all general and additional measurements for shape/morphological measures of large cutting tool types from Khyad. Figure -- clearly shows that there are two centroid groups within the large cutting tools from Khyad. The first group comprised of handaxe, axe blank and biface and the second group with cleaver and cleaver blank, while the other two (pushplane and various biface) stand separately from these two groups.

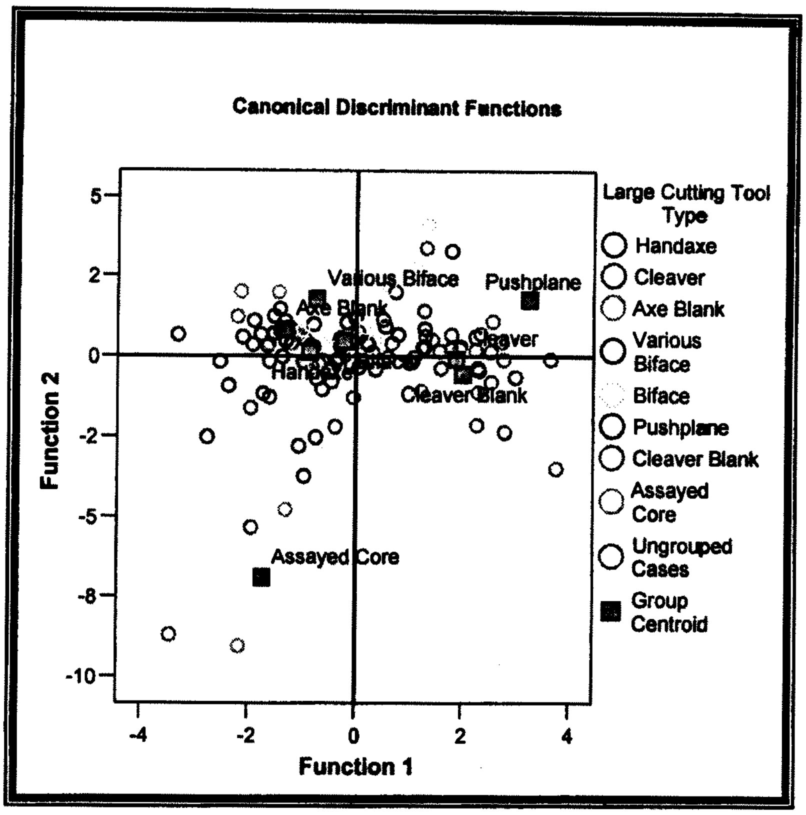

Figure 4.9.1. A scatter plot of discriminant functions 1 and 2 for large cutting tool types from Khyad.

4.10. Accessing variability within large cutting tool types

Effects on variability between and within the large cutting tool types will be explained with the help of variability in raw materials (i.e., types, size and shape) and stages of reduction in the upcoming analysis and the comparison was made between natural clasts type and flaked pieces were also taken up in the upcoming analysis.

Influence of raw material on the variability observed in the large cutting tool types

This portion of analysis examines the frequency of large cutting tools manufactures on specific raw material types. The hypothesis being tested is that raw material physical differences are reflected in large cutting tools measurement and form-defining ratio. Type frequencies and descriptive statistics of large cutting tools by raw material are provided in tabulation form. Raw material types and grain size of raw material on which large cutting tools were manufactured were determined for each specimen (Table 4.10.1 and Table 4.10.2). Large cutting tools were made on three types of raw material namely quartzarenites (quartzite), quartz and dolerite. Quartzarenites (quartzite) (97.5%) is used intensively in the manufacturing of large

cutting tools. The remaining (0.16%) raw material was extremely rare in amount was used at this site. For grain size, majority of large cutting tools were made from arenaceous (1/16 to 2 mm) (98.3%) variety and remaining (1.7%) were made from argillaceous (<1/16 mm) variety.

Table 4.10.1. Large cutting tool types from Khyad site broken down by its raw material types.

Raw Material	Frequency
Quartzarenites (quartzite)	117 (97.5)
Quartz	2 (0.8)
Dolerite	1 (0.8)
Total	**120**

Table 4.10.2. Large cutting tool types from Khyad site broken down by its grain size.

Grain Size of Raw Material	Frequency
Arenaceous (1/16 to 2 mm)	118 (98.3)
Argillaceous (<1/16 mm)	2 (1.7)
Total	**120**

As seen from the above table (Table 4.10.1 and 4.10.2.), majority of large cutting tools were made on quartzarenites (quartzite) with the grain size of 1/16 to 2 mm. Other raw materials like quartz and dolerite are very few in number (n=<5). Due to this long difference in count in the usage of raw material, no statistical analysis could be done in order to test the role played by raw material in large cutting tool variability. In order to test the role of shape and size of raw material few tabulation and statistical test were conducted.

Influence of initial form on the variability observed in the large cutting tool types

Table 4.10.3., provides the mean, standard deviation and coefficient of variation of maximum dimension, maximum width and thickness of large cutting tool types in relation to its initial form types. Blocky and cobbles are excluded from this study because of low count. Table 4.10.3., shows that handaxe made on slab are much longer, wider and thicker than others. Handaxes made on flakes are longer,

wider and thinner than indeterminate. Axe blanks and cleaver blanks are made only on flakes. Both cleavers and biface made on indeterminate are longer and thicker.

Maximum dimension of handaxes made from flakes, slabs and indeterminate show a high variation among the observation when compared to other initial forms. Standard deviation of maximum width and thickness within the flake as initial form is low when compared to slab and indeterminate. High variation in the maximum dimension of flakes indicates a wide spread of maximum dimension values but at the same time less variation seen in the maximum width and thickness of handaxes made on flakes indicates less importance emphasized on reducing the maximum width and thickness of handaxes made on flakes. Standard deviation of maximum width and thickness of handaxe made on blocky have a less value, indicating lesser preference in reducing the width and thickness of original clast size or similarity in selection of clasts size width wise and thickness wise.

Two types of initial forms were used to manufacture cleavers namely flake and indeterminate. Maximum dimension and thickness of cleavers made from flakes show a high variation and low mean value when compared to other initial form. Maximum width of the cleavers made from flake and indeterminate do not show a considerable difference in the standard deviation values. As said in the previous section that indeterminate is the initial form types which has been considerably flaked with little information on initial form types or has a minimum amount of information which could be rightly interpreted. Less variation among the cleavers in maximum dimension and thickness, with indeterminate initial form recorded account to the standardization of size and thickness of this group of cleavers by extensive flaking.

From Khyad, a total of 9 axe blanks were collected in which 7 (63.63%) were sub-angular and 4 (36.36%) were angular. The maximum value of the maximum dimension is from the blocky (188.8 mm) initial types and the minimum value of the maximum dimension is from the slab (125.6 mm).

As the various biface, pushplane and assayed core are low in count, it has been excluded for further analysis.

Table 4.10.3. Mean, standard deviation and coefficient of variation for general metrical measurements of large cutting tool types broken down by its initial form from Khyad.

Type	Initial Form	Variable	Mean	Std. Deviation	CV
Handaxe	Cobble	Maximum Dimension	185.2	5.6	0.03
		Maximum Width	103.9	1.3	0.01
		Thickness	68.9	10.8	0.16
	Blocky	Maximum Dimension	162.2	12.6	0.08
		Maximum Width	84.9	7.2	0.08
		Thickness	55.9	9.6	0.17
	Slab	Maximum Dimension	155.1	26.6	0.17
		Maximum Width	84.8	15.3	0.18
		Thickness	45	14	0.31
	Flake	Maximum Dimension	134.1	22.5	0.17
		Maximum Width	83.6	9.9	0.12
		Thickness	38.1	9	0.24
	Indeterminate	Maximum Dimension	130	28.3	0.22
		Maximum Width	83.3	13.4	0.16
		Thickness	42.2	10.2	0.24
Cleaver	Flake	Maximum Dimension	132.3	21.9	0.17
		Maximum Width	88.6	10.3	0.12
		Thickness	41.5	11.3	0.27
	Indeterminate	Maximum Dimension	157.5	2.6	0.02
		Maximum Width	87.9	11.5	0.13
		Thickness	49.7	9.8	0.2
Axe Blank	Flake	Maximum Dimension	148.1	18	0.12
		Maximum Width	89.2	10.5	0.12
		Thickness	43.8	9.8	0.22
Biface	Indeterminate	Maximum Dimension	132.9	16.8	0.13
		Maximum Width	79.6	5.7	0.07
		Thickness	45.2	7.4	0.16
	Flake	Maximum Dimension	116.2	9.3	0.08
		Maximum Width	71.4	6	0.08
		Thickness	35.9	7.9	0.22
Cleaver Blank	Flake	Maximum Dimension	139.2	18.5	0.13
		Maximum Width	98.3	14.6	0.15
		Thickness	43	14.7	0.34

Table 4.10.3., shows that handaxe were made from slab, flake and indeterminate. The handaxe which were made from slab had a high mean value (1.84) and low coefficient of variation value (CV=0.10) for elongation index value,

indicating that handaxe which were made from slabs are more elongated and has longer tip (99.6) with less variation within them. The mean value for edge shape (0.79), refinement (2.26) and base length (55.6) of handaxe made from flakes are higher than others, and the mean value for tip length is high in the handaxe made from slab (99.6). All these indicate that handaxe which are made from flakes are broader and refined than handaxes made from slab and indeterminate. The base length for handaxes made from flakes is also high.

When handaxe made on flakes are compared with axe blanks made on flakes (axe blanks are only made on flakes), the elongation, tip length and base length value in axe blanks are higher than handaxe. While the other index values like edge shape and refinement for handaxes are higher, suggesting handaxes are shorter, broader and thinner with less base length and tip length value. Whereas axe blanks are longer, narrower and thicker with high base length and tip length value. Hence all these indicate that handaxes are made from axe blanks.

From Table 4.10.3., it is clearly understood that the cleavers are longer, broader and thicker with less base length and high tip length, whereas cleaver blanks are shorter, narrower, and thinner with high base length and low tip length value, because least amount of reduction took place on the cleaver blank. As the reduction continues from cleaver blank to cleaver, narrower and thinner cleaver blanks become broader and thicker, as the cleaver blanks are made from predetermined flakes they are thinner. Variation is noticed more on edge shape and tip length of cleavers, whereas the elongation, refinement and base length in cleaver blank show much variation. This suggests that the cleavers are similar to each other in elongation, refinement and base length.

The initial form for biface are flakes and indeterminate. Biface made from indeterminate are elongated and broader with high base length and tip length. Whereas biface made from flakes are shorter, narrower and are more refined than indeterminate.

Handaxes which are made from indeterminate shows high variation in elongation, edge shape, base length and tip length. Whereas variation in refinement is seen only on the handaxes which are made from slab. When the handaxes made from flakes are compared with the axe blanks which are also made from flake, the

elongation, edge shape, base length and tip length show much variation on handaxe than the axe blanks made on flakes. But, high variation is noticed for refinement in the axe blank when compared to handaxe as the axe blanks are made from a predetermined flake, which has thin cross section.

Bifaces made on determinate show much variation in the elongation, edge shape, base length and base length value. Bifaces made on flake show much variation in the refinement index value.

Table 4.10.4. Mean, standard deviation and coefficient of variation for shape defining index ratio measurements of large cutting tool types broken down by its initial form from Khyad.

Type	Initial Form	Index	Mean	Std. Deviation	CV
Handaxe	Slab	Elongation	1.84	0.18	0.10
		Edge Shape	0.58	0.09	0.16
		Refinement	1.99	0.52	0.26
		Base Length	55.5	11.5	0.21
		Tip Length	99.6	20.3	0.20
	Flake	Elongation	1.58	0.17	0.11
		Edge Shape	0.79	0.16	0.20
		Refinement	2.26	0.36	0.16
		Base Length	55.6	10.7	0.19
		Tip Length	75.3	13.3	0.18
	Indeterminate	Elongation	1.57	0.2	0.13
		Edge Shape	0.76	0.18	0.23
		Refinement	2.03	0.37	0.18
		Base Length	53.4	12.5	0.23
		Tip Length	77.1	24.4	0.32
Axe Blank	Flake	Elongation	1.66	0.07	0.04
		Edge Shape	0.65	0.1	0.16
		Refinement	2.1	0.37	0.18
		Base Length	65.1	11	0.17
		Tip Length	83.5	12.7	0.15
Cleaver	Flake	Elongation	1.49	0.15	0.10
		Edge Shape	1.09	0.21	0.19
		Refinement	2.25	0.53	0.24
		Base Length	65.4	17.9	0.27
		Tip Length	67.1	23.4	0.35
Cleaver Blank	Flake	Elongation	1.4	0.27	0.19
		Edge Shape	1.06	0.19	0.18
		Refinement	2.45	0.65	0.26
		Base Length	74.8	22.9	0.31
		Tip Length	64	18.3	0.29
Biface	Flake	Elongation	1.66	0.08	0.05
		Edge Shape	0.77	0.04	0.06
		Refinement	2.05	0.33	0.16
		Base Length	49.3	7.67	0.16
		Tip Length	68	2.65	0.04
	Indeterminate	Elongation	1.71	0.1	0.06
		Edge Shape	0.78	0.1	0.12
		Refinement	1.79	0.21	0.12
		Base Length	56.7	9.38	0.17
		Tip Length	79.3	14.4	0.18

Influence of reduction sequence on the variability observed in the large cutting tool types

In order to explain the variability within the large cutting tool types many studies were initiated. Traditionally the variability in large cutting tools was explained due to stylistic and functional aspects. Ashton and Mcnabb (1994) and White (1995) explained the variability within the large cutting tool as the result of size, shape and properties of raw material types and whereas McPherron (1994, 1995, 1999, 2000) has explained the variability in large cutting tools as the result of bifacial reduction. In other instances Dibble (1984, 1987) and Dibble and Whittaker (1981) have explained the variability in lithic assemblage due to the reduction intensity and this could be well explained if the original nodule or blank size is compared with the actual handaxe size. Though intensity of reduction can be generally quantified with size measures and the percentage of remaining cortex, the reduction model outlined here focuses primarily on the changes on the shape that occur when the tip is reworked. Thus tip length will be the primary measure of reduction intensity (McPherron 1999). As described by McPherron the traditional model, elongation, refinement and edge shape will vary independently of tip length. On the other hand, the reduction model predicts that elongation and edge shape will vary directly with reduction intensity as measured by tip length (McPherron 1999).

The reduction model predicts that refinement will at first rise, then follow a period of relative stability, and begin to decrease only in the final stages. An assemblage representing all stages of reduction or only the middle stage will look exactly like a traditional assemblage where there is no relationship between reduction intensity and shape.

In present study the variability in large cutting tools will be explained with the method used by McPherron (McPherron, 1999). The hypothesis being tested is that raw material physical differences are reflected in large cutting tools measurement and form-defining ratio. Out of 120 large cutting tools from the Khyad, 54 of them were handaxe, 9 axe blanks, 25 cleavers, 9 cleaver blank, 10 bifaces, 2 assayed cores, 2 pushplanes and 1 various biface. As the assayed core, pushplane and various biface types has the low count (<5), it has been excluded from the further analysis because it won't give any meaningful results.

Testing reduction model to explain the variability in large cutting tools.

As suggested by McPherron (1999), a reduction model should be addressed with the help of elongation, refinement and edge shape index ratio and this in turn will explain the variability. This above statement of McPherron will be addressed in the following section.

Figure 4.10.1., reveals that as the tip length decreases, the large cutting tool becomes less elongated and less pointed (Figure 4.10.1). In the case of refinement, the relationship moves in different directions as the tip length decreases, refinement increases (Figure 4.10.3). These patterns are indicative of the early to middle stage of reduction where refinement increases as more of the natural clast is worked.

Flake scar count and index of invasiveness would also indicate the reductive stages for large cutting tools. Total flake scar count and Invasiveness measure is significantly different between the large cutting tool types with 0.00 level of significance based on ANOVA test. When total flake scar count for large cutting tool types is evaluate handaxe (52) have the highest flake scar count then comes the second largest flake scar count is of cleaver (36) followed by biface (33), axe blank (30), various biface (25), assayed core (17) and the lowest flake scars have been recorded on the cleaver blank (16). Maximum dimension of handaxes and cleavers is not at all significant with the total flake scar count. In this figure assayed core and various biface are included yet these types have a low (<5) count (Figure 4.10.5). In Figure 4.10.6., the R Sq Linear (0.024) depicts the insignificant value when compared with the maximum dimension and total flake scar count. The continuous flaking of a tool will cause the reduction in the size and increase in the flake scar count, this kind of phenomena is seen from the large cutting tools of Khyad.

If elongation, edge shape and refinement index are compared with total scar count a reduction model can be obtained and this in turn will show the variability in large cutting tools from Khyad. Simple regression plots with linear regression line will explain the relationship between the variables selected for inferences. A simple scatter pot with linear regression line explains that as the total scar count increases, the index of invasiveness also increases among large cutting tools. Elongated large cutting tools have more flake scar count and with more index of invasive values. Shorter large cutting tools have less flake scar count with less index of invasive

index. Broader large cutting tools have high index of invasive with more number of flake scar count. Refined large cutting tools from Khyad have more number of total flake scar count, but the index of invasiveness is constant with little amount of variance in them.

As the scatter plot and its description indicates that when the level of reduction decreases, the tools become elongated and narrower with less refined and as the reduction intensity increases the tools turn out to be shorter and broader and the refinement also increases considerably (Figure 4.10.6 to 4.10.16).

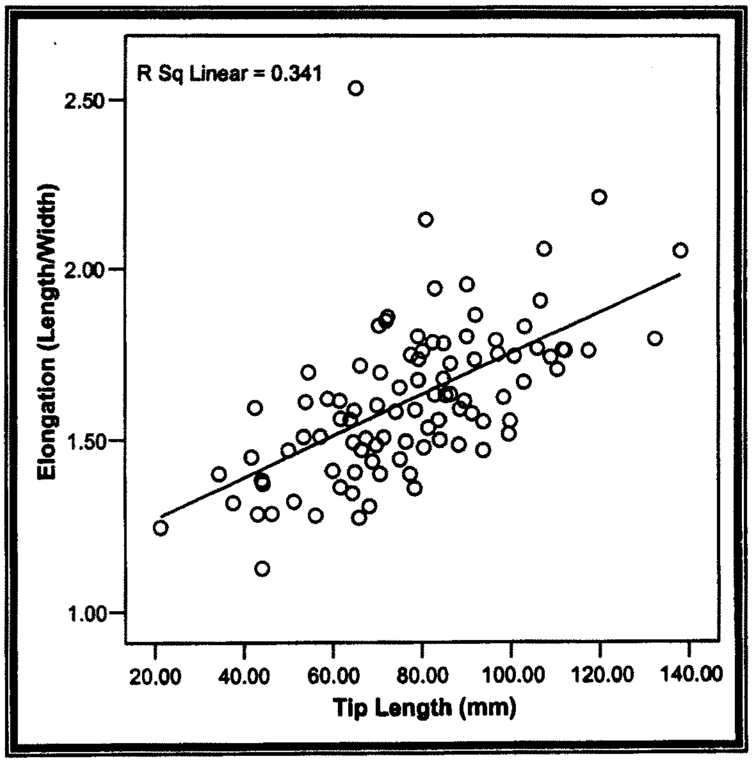

Figure 4.10.1. A scatter plot with simple linear regression of tip length versus elongation index ratio (length/width) for large cutting tools from Khyad.

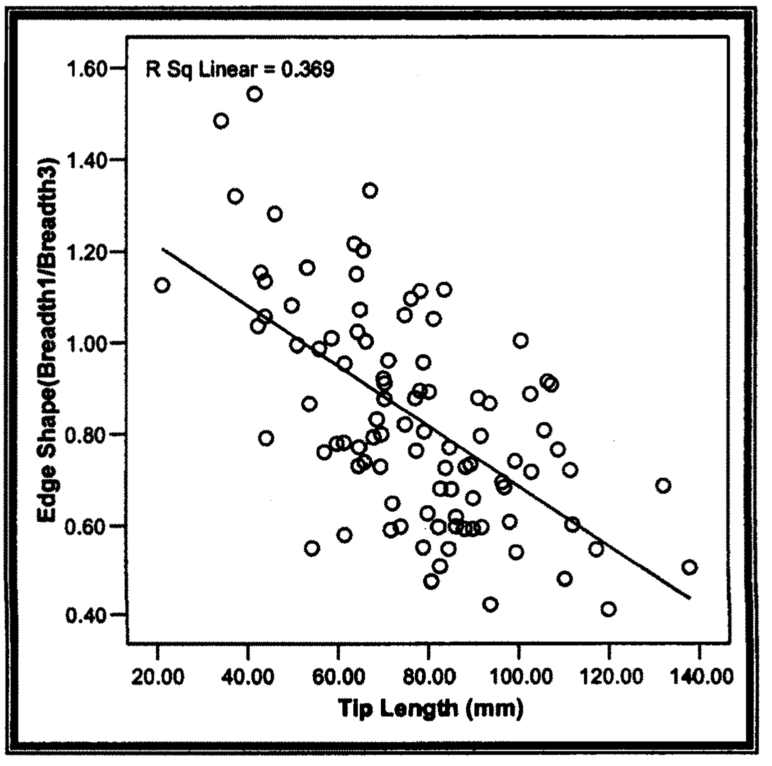

Figure 4.10.2. A scatter plot with simple linear regression of tip length versus edge shape index ratio (breadthl/breadth3) for large cutting tools from Khyad.

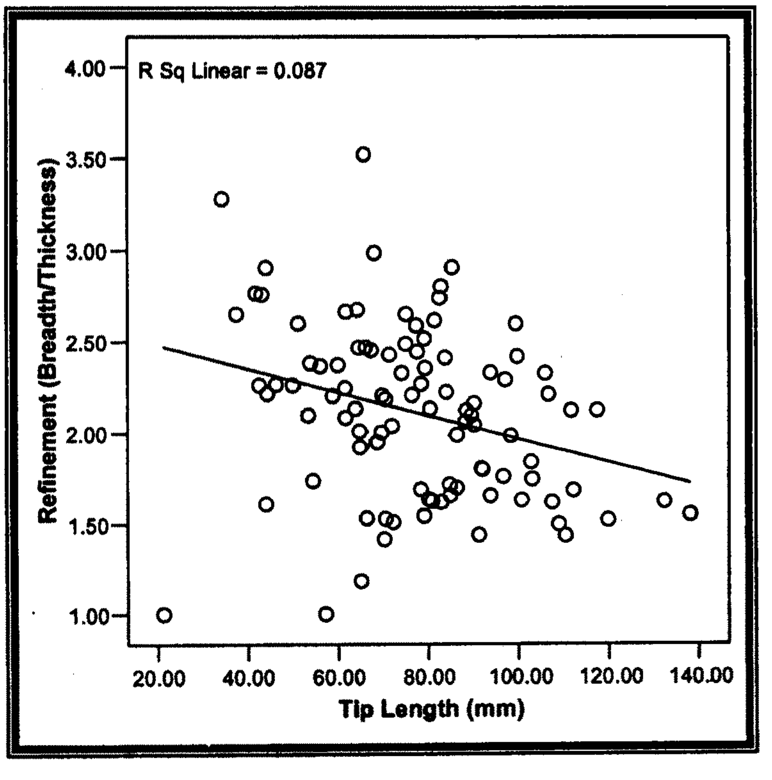

Figure 4.10.3. A scatter plot with simple linear regression of tip length versus refinement index ratio (width/thickness) for large cutting tools from Khyad.

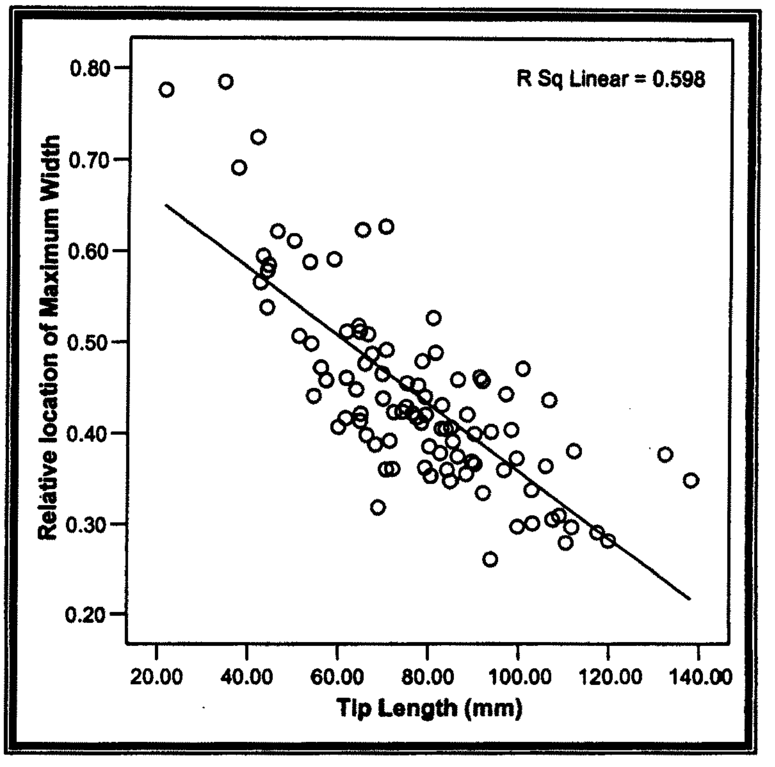

Figure 4.10.4. A scatter plot with simple linear regression of tip length versus relative location of maximum width for large cutting tools from Khyad

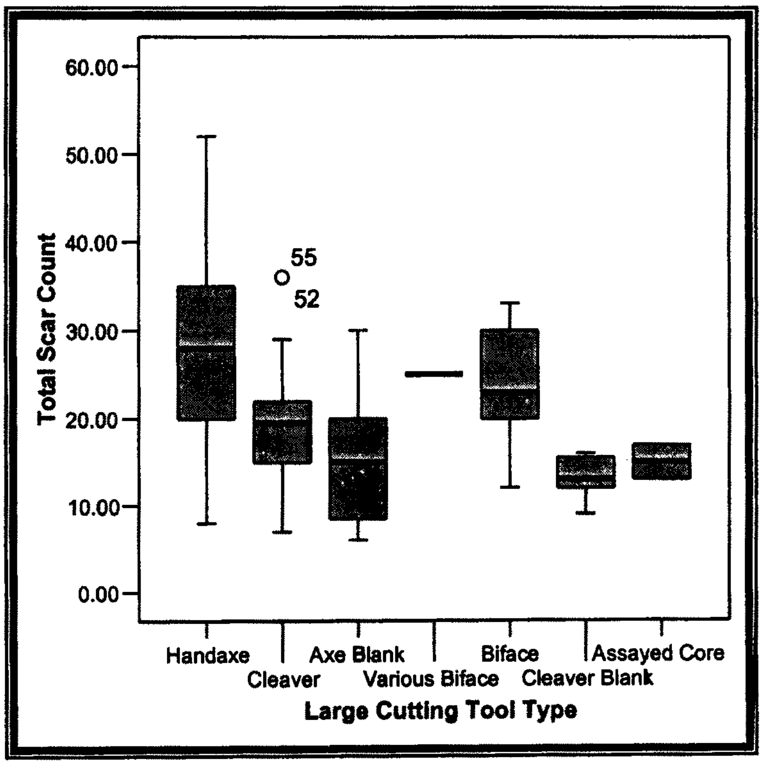

Figure 4.10.5. Box plot for dorsal scar count of large cutting tools from Khyad.

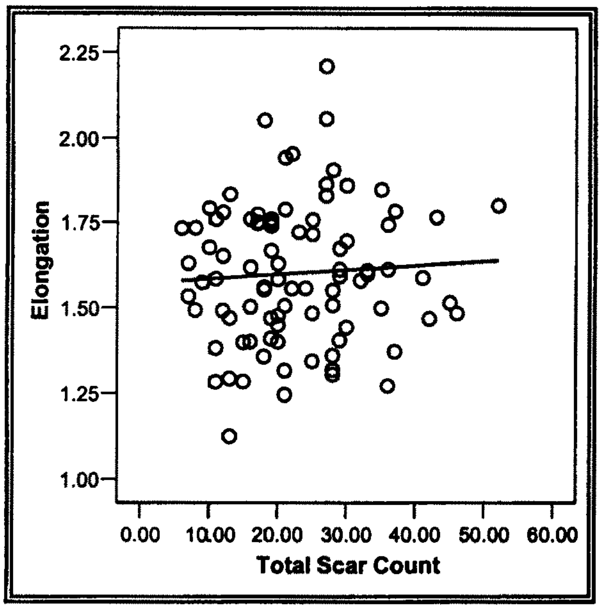

Figure 4.10.6.

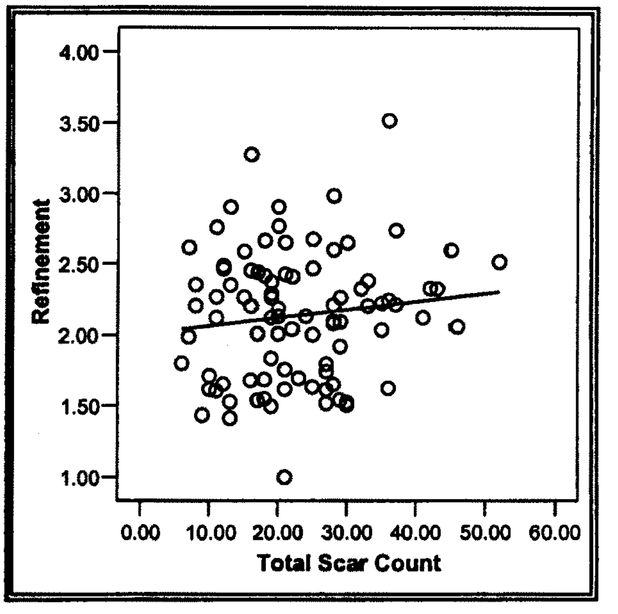

Figure 4.10.7.

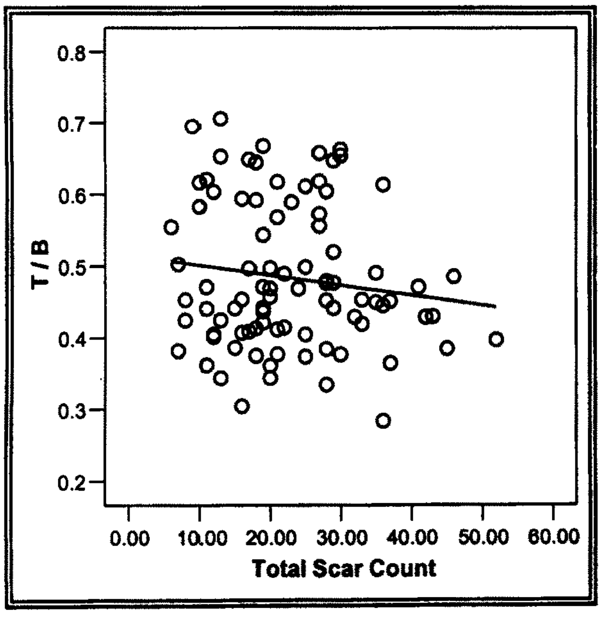

Figure 4.10.8.

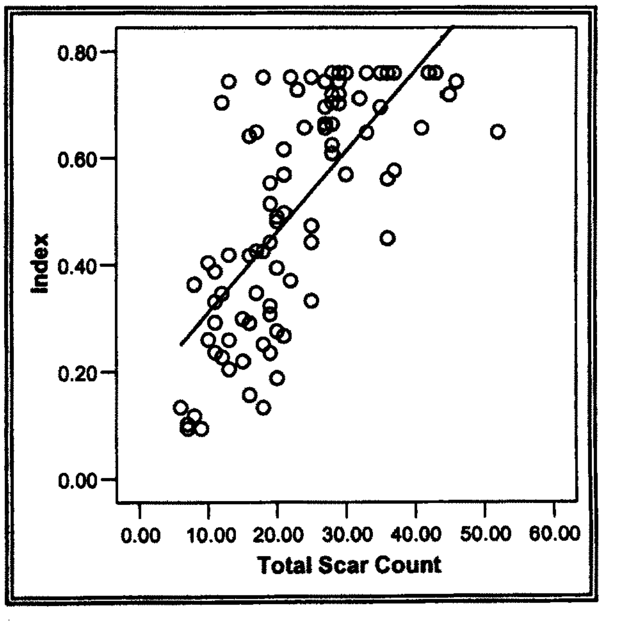

Figure 4.10.9.

Figure 4.10.6 to 4.10.9. Scatter plot for mapping the morphological changes in large cutting tools, when they are compared with the total scar count by shape defining index ratio from Khyad.

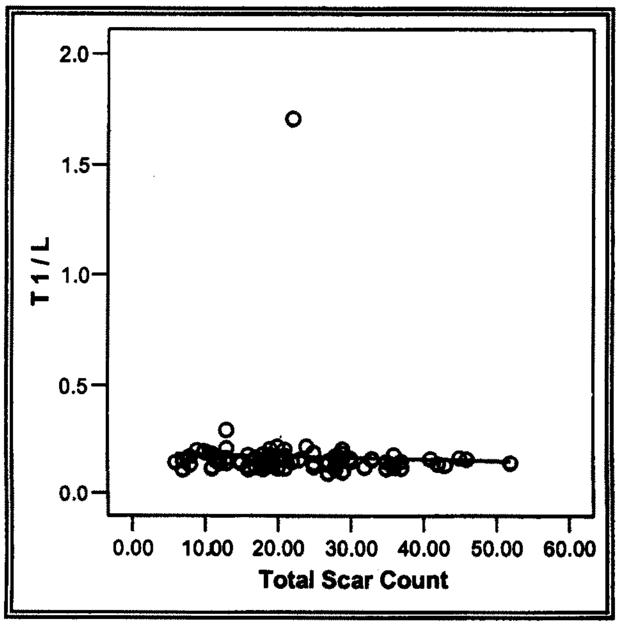

Figure 4.10.10

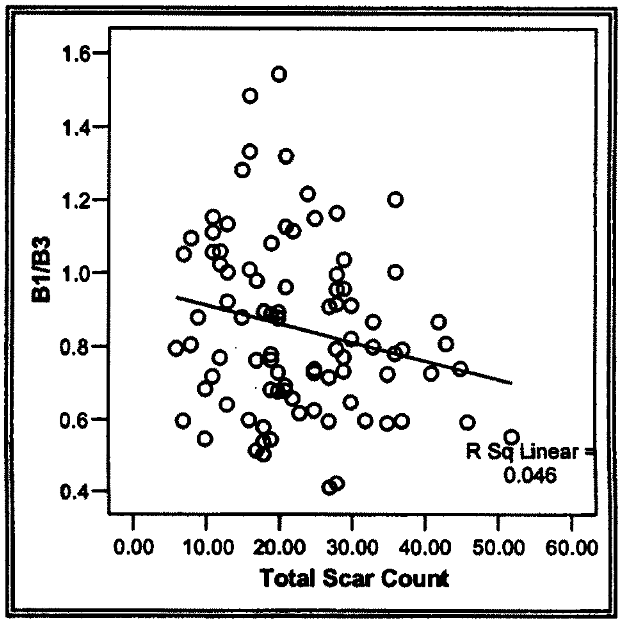

Figure 4.10.11.

Figure 4.10.10 to 4.10.11. Scatter plot for mapping the morphological changes in large cutting tools, when they are compared with the total scar count by shape defining index ratio from Khyad.

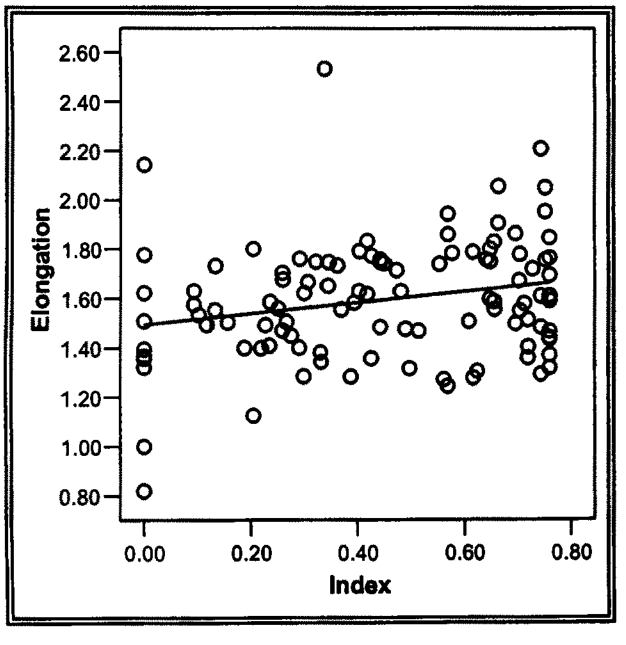

Figure 4.10.12.

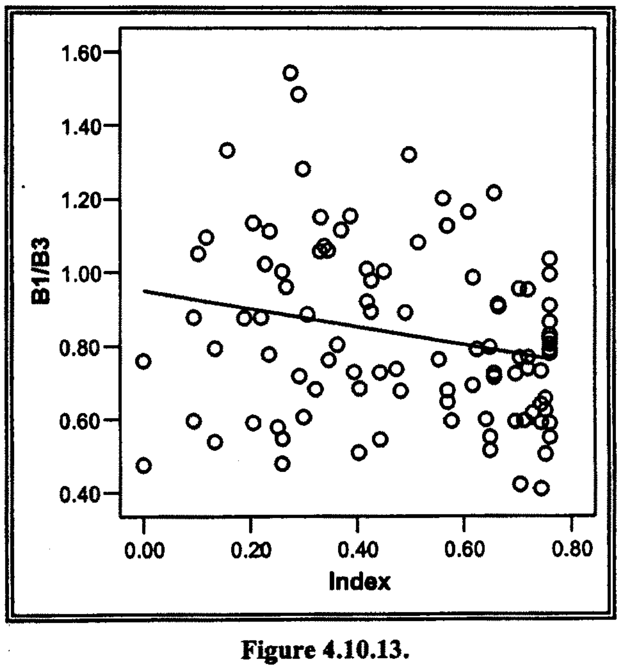

Figure 4.10.13.

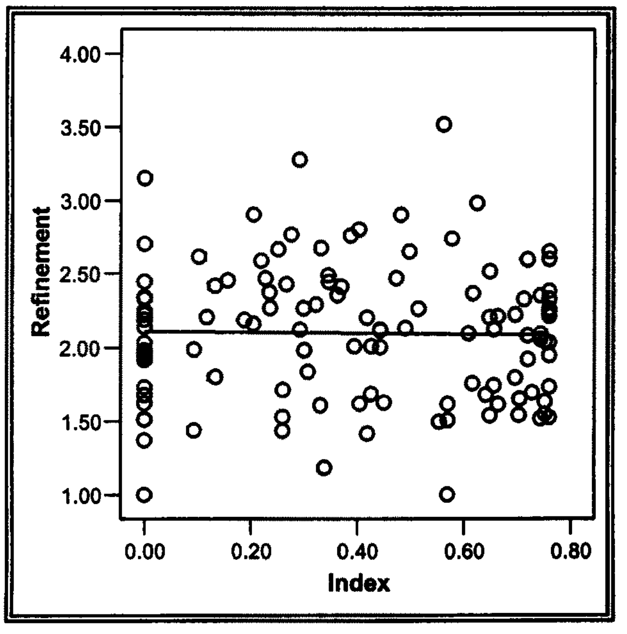

Figure 4.10.14.

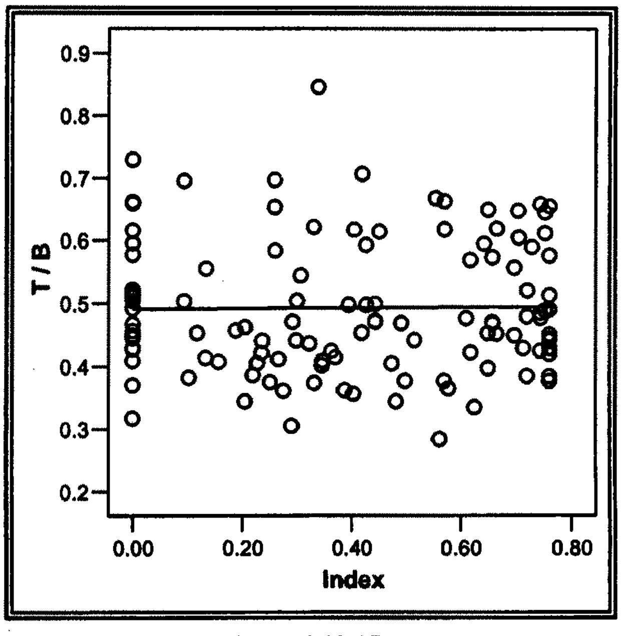

Figure 4.10.15.

Figure 4.10.12 to 4.10.15. Scatter plot for mapping the morphological changes in large cutting tools, when they are compared with the index of invasiveness by shape defining index ratio from Khyad.

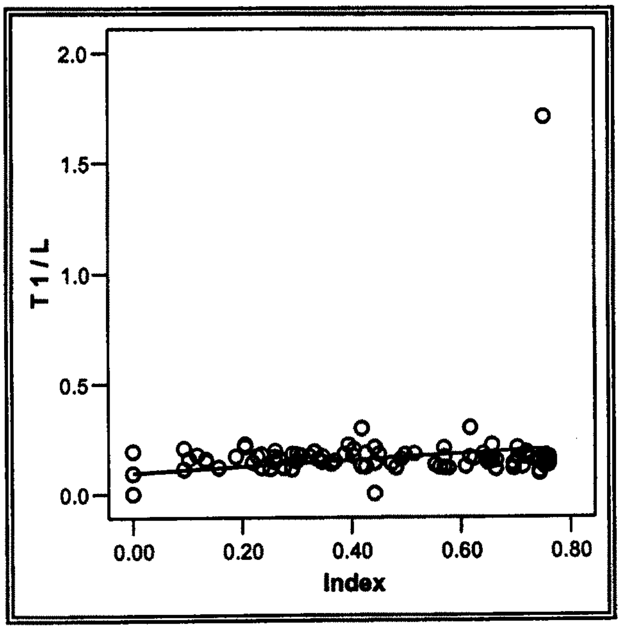

Figure 4.10.16. Scatter plot for mapping the morphological changes in large cutting tools, when they are compared with the index of invasiveness by shape defining index ratio from Khyad.

Comparison between axe blank and handaxe for accessing the reduction sequence.

In order to explain the reduction and variability present in handaxe will be explained with the help of comparing metrical and non-metrical attributes which define the size and shape of large cutting tools. These measurements are compared between axe blanks and handaxe in order to explain the reduction and variability present.

One-Way ANOVA test for these attributes of handaxe and axe blank are not at all significant. In order to explain, in what way these attributes are not significant, a stem and leaf plots was used which explains the mean value and its interquartile range with its extreme values in a visual way.

Common metrical attributes like maximum dimension (length), maximum width and thickness are recorded in order to define the morphology of the tools. Table 4.10.5., shows, the mean value of maximum dimension, thickness and weight for axe blank is higher; whereas the mean value for maximum width of handaxe is higher than axe blank. The reason might be, handaxe was made from variety of initial forms than axe blank and the count of the handaxe was also higher than the axe blank. One more reason is that the mean value gets affected because the handaxe which was made from cobble and heat spall has the highest maximum width value.

The standard deviation (28.1) and the interquartile range (43.3) for maximum dimension of handaxe is higher than the axe blank (std.deviaiton-22.5 and interquartile range-38.4), suggesting that there was a great deal of variation within handaxe type. The standard deviation and interquartile range for thickness of axe blanks is higher than handaxe.

Standard deviation and the interquartile range of weight measure for axe blank are higher than handaxe and at the same time interquartile range of axe blank is higher than handaxe and whereas standard deviation for maximum width of the axe blank and handaxe are equal. As the standard deviation and interquartile range of axe blank in thickness and weight is higher than the handaxe and when the maximum width is concerned, the standard deviation of axe blank and handaxe are equal (12.8), with the higher interquartile range of axe blank. Thus, it is very clear that, the handaxes must have been reduced from the axe blank and they haven't been

completely reduced, because as both, the standard deviation and interquartile range value for maximum dimension of handaxe is higher than axe blank and the high standard deviation value for thickness and weight of axe blanks indicates reduction from axe blank to handaxe and at the same time the maximum width value for the axe blank (12.8) and handaxe (12.8) in standard deviation are same, indicating less reduction of width. It is obvious from the above statement that the handaxe from Khyad have been reduced from the axe blank and they are in the middle stage of reduction as witnessed by low reduction at the width (this statement has been taken for further examination in the subsequent section).

Table 4.10.5. Mean, standard deviation shows the tabulation of axe blank and handaxe types by general metrical measurements from Khyad

Type	Variable	Mean	Standard Deviation	Interquartile Range	CV
Axe Blank	Maximum Dimension	147.5	22.5	38.4	0.15
	Maximum Width	84.6	12.8	23.3	0.15
	Thickness	45.5	13.6	19.1	0.30
	Weight	684	485	391	0.71
Handaxe	Maximum Dimension	139.2	28.1	43.3	0.20
	Maximum Width	85.1	12.8	19.3	0.15
	Thickness	41.1	10.4	12.6	0.25
	Weight	498	289	272	0.58

Comparison of additional attributes for defining morphology:

As already stated in the Chapter 1, additional attributes for measuring morphology of the tools like tip width (B1), mid width (B2), base width (B3), tip thickness (T1), mid thickness (T2), base thickness (T3), tip length and base length were compared from both the axe blank and handaxe in order to explain the effect of reduction over the variability of these two types. Table 4.10.6., shows the mean, standard deviation and interquartile range value for these above said additional attributes. The mean and standard deviation value for the tip length of handaxe is higher than axe blank with high interquartile range. For the base length of axe blank the mean, standard deviation and interquartile range are higher than handaxe. From these two attributes it is clear that, as the reduction increases the tip length of handaxe increases with decreasing base length, when it is compared to axe blank.

When the tip width of handaxe is taken into account the mean value and interquartile range is high, but the standard deviation value is lower than axe blank. This indicates that as the reduction increases the tip width becomes narrower with less variation in them and the range of the tip width is higher in handaxe than axe blank due to the increase in counts of handaxe. Handaxe's mid width value for mean, standard deviation, interquartile range and the coefficients of variation is lower than the axe blank, but the mean value is higher in axe blank, indicative of, as the reduction is in progress the axe blank's mid width decreases. But the mean value of handaxe (83.06) is marginally lower than axe blank (84.38), suggesting less reduction on the mid portion of the specimen. The base width of handaxe has low mean value with high standard deviation value suggesting that as the reduction increases the mean value decreases in handaxe than axe blank, whereas high standard deviation value for handaxe shows more variability in the base width as the reduction increases.

Table 4.10.6. Mean, standard deviation shows the tabulation of axe blank and handaxe types by additional metrical measurements from Khyad

Type	Variable	Mean	Standard Deviation	Interquartile Range	CV
Axe Blank	Tip Length	81.5	11.8	19.7	0.14
	Base Length	68.3	21.4	22.1	0.31
	Tip Width	52.21	13.54	15.27	0.26
	Mid Width	84.38	12.91	23.66	0.15
	Base Width	77.97	11.19	18.99	0.14
	Tip Thickness	50.60	73.20	23.60	1.45
	Mid Thickness	43.80	13.10	14.80	0.30
	Base Thickness	42.50	14.80	21.20	0.35
Handaxe	Tip Length	82.3	22.3	30.0	0.27
	Base Length	55.2	12.5	15.3	0.23
	Tip Width	53.75	12.06	16.67	0.22
	Mid Width	83.06	12.03	15.63	0.14
	Base Width	73.34	12.60	18.48	0.17
	Tip Thickness	21.40	6.20	42.70	0.29
	Mid Thickness	39.20	9.40	13.50	0.24
	Base Thickness	34.60	9.80	12.60	0.28

Measurements which were generate to defining edge shape, elongation and refinement ratios were compared within themselves:

The measurements that were taken from the tools were then used to generate the edge shape, elongation and refinement rations. Edge shape was obtained by dividing the tip width (B1) by base width (B3), elongation was obtained by dividing the length/breadth (L/B) and refinement was obtained by dividing thickness/breadth (T/B). As reduction increases, the ratio of edge shape, elongation and refinement changes and these changes are as follows,

- as reduction increases edge shape ratio decreases i.e., narrower specimens becomes broader
- as reduction increases elongation index decreases i.e., longer specimens becomes shorter and
- as reduction increases refinement ratio also increases i.e., thicker specimens becomes thinner

All those features that were mentioned in the above statement can be noticed by comparing the ratios (i.e., edge shape, elongation and refinement) of axe blank with handaxe.

The mean value for the edge shape of handaxe (0.63) is comparatively very less than the axe blank which has 0.69, indicating narrower axe blank and broader handaxe. As seen in the above mentioned statement, as reduction increases the edge shape tends to get broader and this same aspect of reduction was noticed at Khyad. The mean value for elongation of handaxe is less and the value of standard deviation is more than the axe blank, indicating that the decreasing elongation index value and increasing variation (i.e., more standard deviation value) of handaxe explains that handaxe's are reduced from the axe blanks.

When the reduction increases the refinement ratio also increases. From this site the mean value of handaxe is higher than the axe blank. Whereas the standard deviation value for the handaxe is low, suggesting less variation in the reduced type (handaxe) than the initial form (axe blank).

Table 4.10.7. Mean, standard deviation shows the tabulation of axe blank and handaxe types by shape defining index ratio from Khyad.

Type	Index Ratio	Mean	Std. Deviation	Interquartile Range	CV
Axe Blank	Edge Shape (B1/B3)	0.69	0.13	0.20	17.12
	Elongation (Length/Breadth)	1.75	0.13	0.21	12.23
	Refinment (Breadth/Thickness)	1.95	0.43	0.78	0.22
Handaxe	Edge Shape (B1/B3)	0.63	0.15	0.20	0.24
	Elongation (Length/Breadth)	1.64	0.21	0.30	0.13
	Refinement (Breadth/Thickness)	2.14	0.37	0.55	0.17

In order to examine the reduction sequence on the large cutting tools as well as the morphological changes, a hypothesis was put forward:

- axe blank were the initial stage for handaxes,
- cleaver blank were the initial for cleavers.

Comparisons of non metrical attributes for measuring the reduction sequence:

Total flake scar count, total number of non-feather termination and index of invasiveness will delineate the reduction stages from a given assemblages. As the reduction increases the total scar count, non-feather termination and index also increases. Table 4.10.8., shows, the mean value for total scar count, non-feather termination and index of invasiveness are more in handaxe than axe blanks. The standard deviation value for total scar count and non-feather termination are higher in handaxe, hence this higher mean value for total scar count and non-feather termination in handaxe indicates that this type has been reduced considerably than axe blanks. While the standard deviation value for index of invasiveness is higher in axe blank, indicating more number of variations within the axe blanks.

Table 4.10.8. Mean, standard deviation shows the tabulation of axe blank and handaxe types by additional metrical measurements.

Type	Variable	Mean	Std. Deviation	Interquartile Range	CV
Axe Blank	Total scar count	15.38	8.11	13.25	0.53
	Total no. of non-feather termination	5.25	5.26	8.25	1.00
	Index of invasiveness	0.35	0.22	0.37	0.63
Handaxe	Total scar count	27.79	9.96	15.25	0.36
	Total no. of non-feather termination	10.83	5.78	8.5	0.53
	Index of invasiveness	0.62	0.16	0.25	0.26

Comparison between common metrical attributes:

Common metrical attributes like maximum dimension (length), maximum width and thickness are recorded in order to define the morphology of the tools. From the previous section of this chapter it was proved that cleavers are quite different from other large cutting tools morphologically. Table 4.10.9., shows, cleaver blank with the highest mean value in maximum dimension and maximum width and the lowest mean value in thickness and weight than the cleavers, whereas the cleaver had the lowest mean value in the maximum dimension and in the maximum width, having little bit variation in the mean value of both thickness and weight, indicating the initial form of the cleaver from cleaver blank. High coefficient of variation values of maximum dimension and weight in cleaver types suggest that cleavers are showing much variability than the cleaver blanks. The C.V (coefficient of variation) values of thickness (0.36) for cleaver blanks suggest that they are much more variable than cleavers (0.28), at the same time the maximum width for both have same coefficient values, indicative of less reduction in the width portion. From Table 4.10.9., it can be summed up that the hominins at this site selected a blank which have minimum variation in size and they were much more concerned with the reduction of maximum dimension than reducing the width of the blank.

Table 4.10.9 Mean, standard deviation shows the tabulation of cleaver blank and cleavers types by general metrical measurements.

Type	Variable	Mean	Standard Deviation	Interquartile Range	CV
Cleaver Blank	Maximum Dimension	138.77	19.78	24.01	0.14
	Maximum Width	94.86	11.02	15.83	0.12
	Thickness	43.36	15.68	22.50	0.36
	Weight	570.13	229.33	246.25	0.40
Cleaver	Maximum Dimension	134.78	23.05	31.22	0.17
	Maximum Width	88.93	10.62	14.70	0.12
	Thickness	43.37	11.94	10.74	0.28
	Weight	571.67	280.48	257.00	0.49

Comparison of additional attributes for defining morphology:

Additional attributes for measuring morphology of the tools like tip width (B1), mid width (B2), base width (B3), tip thickness (T1), mid thickness (T2), base thickness (T3), tip length and base length were compared from both the cleaver blank and cleaver in order to explain the effect of reduction over the variability of these two types. The base length, tip width, mid width, base width and tip thickness for cleaver blank is high, this indicates that cleaver blanks were longer and wider than cleaver, whereas the mean value for tip length, mid thickness and bas thickness of cleaver is high indicates that cleavers are marginally thinner than the cleaver blank.

More variation can be seen on the tip length (CV=0.36) and base width (0.12) are high of cleavers, indicating as the reduction is in progress the tip length, mid width and base width become more complex when cleavers are compared to cleaver blank and less variation is seen on base length, thickness of cleavers. As the reduction increases the length, width and the thickness get reduced, but the tip width remains constant, indicating that the tip width remains the same for all the cleavers and the mid width and base width changes as the reduction increases and the thickness of the cleaver at tip, middle and at base remains constant as the cleaver gets reduced.

Table 4.10.9 Mean, standard deviation shows the tabulation of cleaver blank and cleavers types by additional metrical measurements.

Type	Variable	Mean	Standard Deviation	Interquartile Range	CV
Cleaver Blank	Tip Length	64.00	18.34	29.04	0.29
	Base Length	74.77	22.91	25.88	0.31
	Tip Width	84.23	14.21	17.89	0.17
	Mid Width	92.05	8.42	10.16	0.09
	Base Width	80.14	8.88	15.99	0.11
	Tip Thickness	22.06	5.57	4.36	0.25
	Mid Thickness	39.77	15.11	7.40	0.38
	Base Thickness	34.43	11.04	7.84	0.32
Cleaver	Tip Length	71.05	25.43	46.62	0.36
	Base Length	63.74	17.78	28.17	0.28
	Tip Width	79.27	13.77	19.93	0.17
	Mid Width	87.36	10.26	14.35	0.12
	Base Width	75.02	8.71	14.41	0.12
	Tip Thickness	21.00	4.48	5.25	0.21
	Mid Thickness	40.41	8.63	9.66	0.21
	Base Thickness	36.72	8.40	8.23	0.23

Comparisons of measurements were made to generate indices for defining edge shape, elongation and refinement ratios:

The measurements that were taken from the tools, were then used to generate the edge shape, elongation and refinement rations. Edge shape was obtained by dividing the tip width (B1) by base width (B3), elongation was obtained by dividing the length/breadth (L/B) and refinement was obtained by dividing thickness/breadth (T/B).

From Table 4.10.10., the mean value for refinement and edge shape is higher than the cleaver blank whereas the mean value for elongation and CEL/B is higher in cleaver blank. Variation is noticed in refinement, edge shape and elongation in cleaver, this variation can be attested to the increase in reduction of cleavers than cleaver blanks. As the reduction increases the cleaver gets more refined and broader whereas the cleavers get less elongated with more variation.

Table 4.10.10 Mean, standard deviation shows the tabulation of cleaver blank and cleavers types by shape defining ratios.

Type	Variable	Mean	Standard Deviation	Interquartile Range	CV
Cleaver Blank	T / B	0.46	0.14	0.25	0.31
	B1byB3	1.06	0.19	0.21	0.18
	B/L	0.69	0.09	0.09	0.13
	CEL/B	0.82	0.16	0.24	0.20
Cleaver	T / B	0.47	0.11	0.20	0.24
	B1byB3	1.07	0.22	0.25	0.20
	B/L	0.67	0.08	0.13	0.12
	CEL/B	0.78	0.17	0.19	0.22

Comparisons of non metrical attributes for measuring the reduction sequence:

Table 4.10.11., shows that the mean value for total scar count and total number of non-feather termination are high in cleavers than cleaver blanks. The mean value for the index of invasiveness remains the same for cleavers and cleaver blanks. All this indicates that as the reduction continues from cleaver blank to cleaver the total scar count, total number of non-feather termination increases.

Table 4.10.11. Mean, standard deviation shows the tabulation of cleaver blank and cleavers types by additional metrical measurements.

Type	Variable	Mean	Std. Deviation	Interquartile Range	CV
Cleaver Blank	Total Scar Count	13.25	2.38	3.75	0.18
	Total No. of Non-Feather Termination	5	3.63	5.25	0.73
	Index	0.38	0.18	0.31	0.48
Cleaver	Total Scar Count	19.81	8.11	11.50	0.41
	Total No. of Non-Feather Termination	6.57	3.70	6.50	0.56
	Index	0.38	0.18	0.31	0.48

4.11. Site description of Benkaneri (N 15° 52′; E 75°32′)

This site is 5 km west of Lakhmapur village and it is on the western side from the Lakhmapur village (Figure 4.11.1)and is at the foot-slope of the Kaladgi escarpment (Figure 4.11.2). Artifacts were found from the slopes of the escarpment and within the colluvial sediment matrix. A geological transect was laid down from the slopes of the escarpment to the cultivated fields. The goal of this transect was to study the natural clast size (a detailed account is given in the coming section of this chapter).

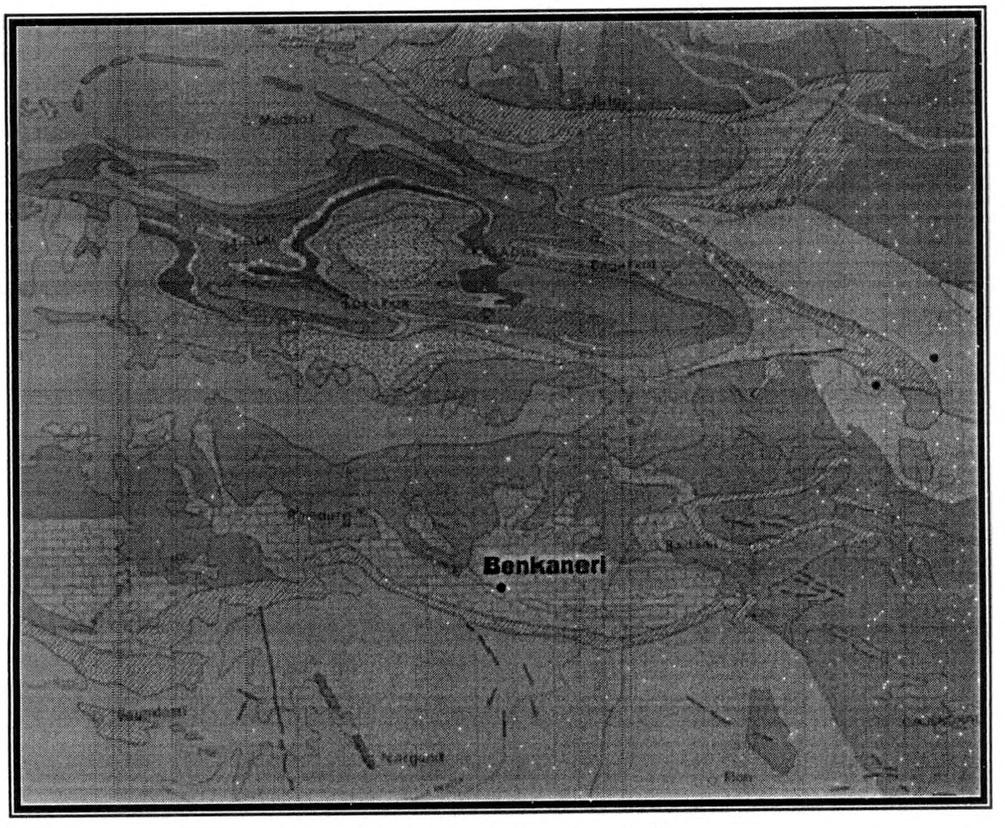

Figure 4.11.1. Location of Benkaneri site.

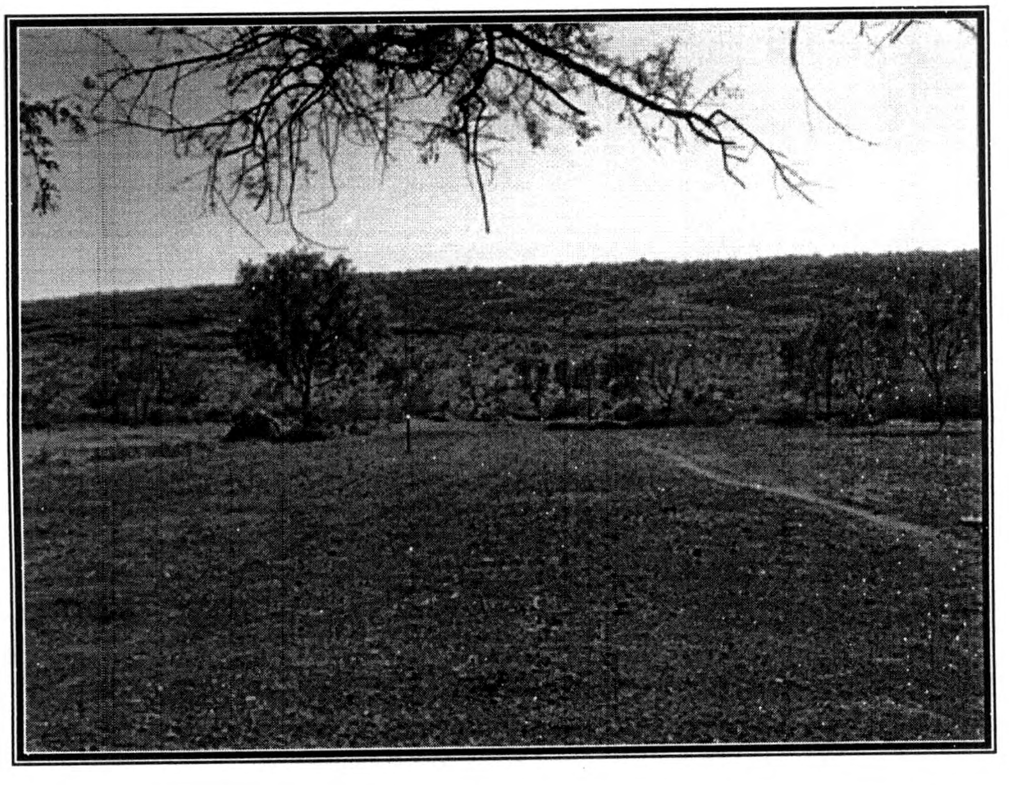

Figure 4.11.2. General view of Benkaneri site.

Description of geological transect laid at Benkaneri

The geological transect measured 240 m from the foothill to the top of the hill. Transect was divided into 24 squares and each square measured 10x5 m. This transect was oriented north-south direction, it was laid just above the trench where the trench was laid by Ravi Korisettar and M.D Petraglia (Petraglia *et al.*, 2003). This transect from Benkaneri have given a lot of information on the change in size and the weathering process and the way how clasts disintegrate from the bed rock (quartzarenites) itself. While collecting and measuring the natural clasts from the respective squares, I noticed there were two exposures (1st exposure at 150 m from the foothill to the top of the hill and the 2nd at 180 m) of quartzarenites (quartzite) from where the clast were coming out and forming the colluvial deposit which was noticed on the slopes and at the foothill. One more interesting information which was collected from this transect was in between 110-120 m, a natural platform like or plain surface measuring 1.5 m in width had 100s of flakes measuring 10-44mm in length. Another noticeable information collected was from 110-170 m, I could collect 5 cleaver and 11 big flakes measuring 175-210 mm (these flakes were in the initial stage of axe manufacturing) from the transect. Between 110-220m bigger size of quartzarenites (quartzite) clast were noticed.

Description of raw material types from the site Benkaneri at Malaprabha Valley

This site yielded artifacts made from quartzarenites (quartzite), quartz, chert, chert breccia and sandstone. Just opposite and north of this site a quartzarenitic ridge was noticed, these quartzarenitic ridge are of Lokapur Subgroup formation. Due to the presences of beddings in these quartzarenites (quartzite), this gets weathered and come out in the form of slabs and in blocky clast (Figure 4.11.2). They are in various colours like white, reddish brown and light brown coloured. In the reddish brown coloured beds, the matrix is replaced by ferruginous cement constituted of a haematitic clayey admixture with very fine sericitic flakes. Other raw material like chert, chert breccia and sandstone are of the exotic variety to this site. The closest occurrences of chert are from Mahakut (approximately 18 km from the site) and Muttalgeri (approximately 9 km from the site). At Mahakut chert breccia are exposed and these chert breccia constitute of poorly sorted sub-angular to angular framework clasts ranging in size up to several tens of cm floating in a

cryptocrystalline (jaspedious or chalcedonic) groundmass (Kale *et al.*, 1996). Sandstones are found in Badami area and this is 17 km away from this site.

Figure 4.11.2. View of beddings in quartzarenites of Lokapur Subgroup formation gets weathered and come out in the form of slabs and in blocky clast.

Degree of roundness of natural clasts

From Benkaneri a total of 60 clasts were measured and from these 50 (83.3 %) were angular, 2 (3.3%) were sub-angular, 7 (11.7%) were sub-rounded and only 1 (1.7%) are rounded ones. Variation in the length (124.4), thickness (53.5) and weight (1681.7) of sub-rounded clast are much higher than the any other clast types. Angular clast types also showed much variation with its length, width, thickness and weight. Minimum length of the sub-rounded clasts starts from 102.9 mm and the maximum is 425 and for angular clast the minimum was 19.3 mm and maximum is 381.7 mm.

Table 4.11.1 For roundness of clast inferred from the transect at Benkaneri:

Variable	Degree of Roundness of natural clast	N	Mean	Minimum	Maximum	Std. Deviation
Length	Angular	50	174.4	19.3	381.7	105.6
	Sub-Angular	2	124.4	54.3	194.6	99.2
	Sub-Rounded	7	257.1	102.9	425	124.4
	Rounded	1	131	131	131	0
Width	Angular	50	102.6	14	206	55.4
	Sub-Angular	2	89.2	51.2	127.1	53.7
	Sub-Rounded	7	142.2	71	214	52
	Rounded	1	95.2	95.2	95.2	0
Thickness	Angular	50	63.2	7.6	192.7	48.3
	Sub-Angular	2	63.8	46.6	81	24.3
	Sub-Rounded	7	125.7	60.7	212.7	53.5
	Rounded	1	67.4	67.4	67.4	0
Weight	Angular	50	1778.7	2	4987	1459.8
	Sub-Angular	2	842.5	159	1526	966.6
	Sub-Rounded	7	2613.4	337	4598	1681.7
	Rounded	1	868	868	868	0

The rounded clast type is much thicker than the angular clast and the thickness of these rounded clast range from 28 to 82 mm, but for the angular clast the range is from 29.6 to 56.7 mm with less standard deviation (8) indicating a lesser variation in the distribution of. Variation in between the length and weight of the angular and rounded clast, angular clasts has a higher value of standard deviation than the rounded clast. Regarding the width and thickness, the rounded clast has a higher value of standard deviation than the angular clast type.

Types of natural clast

The transect which was laid at Benkaneri revealed 60 natural clast from that 45 (75%) of them were slab type, 14 (23.3%) of them were blocky type and only 1 (1.7%) was pebble type. When the mean value of each natural clasts is compared, it shows greater differences only in the blocky type than the other two types. The maximum dimension (274.2 mm), maximum width (155.5 mm), thickness (121.9 mm) and weight (3150.8 mm) of the blocky type was higher than the other two of the natural clast types like slab and pebble. Whereas, the same maximum dimension (36.6 mm), maximum width (33.4 mm), thickness (21.7 mm) and weight (30 mm) for the pebble was lower.

Table 4.11.2. Shows the length, width, thickness and weight of the natural clasts types from Benkaneri.

Variable	Type of Natural Clasts	N	Mean	Minimum	Maximum	Std. Deviation
Length	Slab	45	156.1	19.3	332.1	90.3
	Blocky	14	274.2	32.8	425	115
	Pebble	1	36.6	36.6	36.6	0
Width	Slab	45	93	14	180.1	47.1
	Blocky	14	155.5	28.2	214	51.9
	Pebble	1	33.4	33.4	33.4	0
Thickness	Slab	45	55.6	7.6	189.3	39.3
	Blocky	14	121.9	19.7	212.7	54.7
	Pebble	1	21.7	21.7	21.7	0
Weight	Slab	45	1458.7	2	3911	1220.8
	Blocky	14	3150.8	28	4987	1523.5
	Pebble	1	30	30	30	0

4.12. Lithics from Benkaneri

Benkaneri revealed a total of 125 artifacts, out of this, 87 were debitage (complete flake=37 and broken flake=50) and remaining 38 are flaked pieces. Out of these flaked pieces, 19 (15.2%) are large cutting tools (complete=14 and broken=5), 14 (11.2%) are cores and remaining 5 (4%) were retouched tools.

Table 4.12.1. Frequency table for artifact forms from Benkaneri.

Artifact Types		Counts	Percentage
Debitage	Complete Flake	37	29.6
	Broken Flake	50	40
Flaked Piece	LCT's	14	11.2
	Broken LCT's	5	4
	Core	14	11.2
	Retouched Tool	5	4
Total		125	

•

Table 4.12.1., provides tabulations of lithic assemblage composition by artifact forms and raw material types. Proportions are in parentheses by row. Table 4.12.1., shows that majority of flaked pieces (30.4%) and its resulting debitage (68.8%) were made from quartzarenites (quartzite) (122). Only 2 flaked pieces (Core) were made from chert and chert breccia and one complete flake made on sandstone was collected. From these flaked pieces, all large cutting tools (19), cores (14) and retouched (5) were made from quartzarenites (quartzite).

Table 4.12.2. Frequency of artifact forms by raw material types from Benkaneri.

Raw Material	Debitage		Flaked piece				Grand Total
	Broken Flake	Complete Flake	LCT's	Broken LCT's	Core	Retouched Tool	
Chert	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (100)	0 (0.00)	1 (0.8)
Quartzarenites (quartzite)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (100)	0 (0.00)	1 (0.8)
Quartzarenites (quartzite)	50 (40.9)	36 (29.5)	14 (11.5)	5 (4.09)	12 (9.8)	5 (4.09)	122 (97.6)
Sandstone	0 (0.00)	1 (100)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.8)
Total	**50 (40)**	**37 (29.6)**	**14 (11.2)**	**5 (4)**	**14 (11.2)**	**5 (4)**	**125**

Table 4.12.2. Frequency of artifact forms by grain size types from Benkaneri.

Raw Material	Debitage		Flaked Piece				Grand Total
	Broken Flake	Complete Flake	LCT's	Broken LCT's	Core	Retouched Tool	
<1/16 mm	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (100)	0 (0.00)	1 (0.8)
1/16 to 2 mm	50 (40.98)	36 (29.5)	14 (11.47)	5 (4.09)	12 (9.83)	5 (4.09)	122 (97.6)
>2 mm	0 (0.00)	1 (50)	0 (0.00)	0 (0.00)	1 (50)	0 (0.00)	2 (1.6)
Total	50 (40)	37 (29.6)	14 (11.2)	5 (4)	14 (11.2)	5 (4)	125

The above table provides a comparison between grain sizes of raw material with artifact form. Proportions are in parentheses by rows except the totals for grain size. The raw material with 1/16 to 2 mm (Arenaceous) grain size was the most preferred raw material for all artifact forms. All large cutting tools and retouched tools were made from 1/16 to 2 mm (Arenaceous) grain size type. Majority of cores (12) and debitage (86) were also made from raw material which had 1/16 to 2 mm

(Arenaceous) grain size. From 38 flaked pieces, only 2 were made from chert and chert breccia and out of 87 debitage only 1 was of >2 mm grain size (chert breccia).

4.13. Flaked piece type from Benkaneri

A total of 38 (30.4) flaked pieces were identified from this site. Several important attribute recorded in order to understand the variability of lithic assemblage from this site. Table 4.13.1., provides the tabulation of flaked pieces by raw material types. Proportions are in rows and in column. All large cutting tools types (handaxe, axe blanks, cleaver, cleaver blank and pick), chopper and retouched tools were made from quartzarenites (quartzite). Out of 14 cores 12 were made from quartzarenites (quartzite) and other 2 were made from chert (7.7%) and chert breccia (7.7%).

Table 4.13.1. Frequency of flaked piece by raw material types from Benkaneri.

Flaked Piece		Chert	Chert Breccia	Quartzarenites	Total
Large Cutting Tools	Handaxe	0 (0.00)	0 (0.00)	9 (100)	9 (23.7)
	Axe Blank	0 (0.00)	0 (0.00)	4 (100)	4 (10.5)
	Cleaver	0 (0.00)	0 (0.00)	1 (100)	1 (2.6)
	Cleaver Blank	0 (0.00)	0 (0.00)	1 (100)	1 (2.6)
	Pick	0 (0.00)	0 (0.00)	3 (100)	3 (7.9)
Chopper	Bifacial Chopper	0 (0.00)	0 (0.00)	1 (100)	1 (2.6)
Cores	Bidirectional	0 (0.00)	0 (0.00)	1 (100)	1 (2.6)
	Multi-Platform	1 (7.7)	1 (7.7)	11 (84.6)	13 (34.2)
Retouched Tool	Concave Side Scraper	0 (0.00)	0 (0.00)	2 (100)	2 (5.3)
	Notched Tool	0 (0.00)	0 (0.00)	3 (100)	3 (7.9)
Total		1	1	36	38

Majority of flaked piece were made from 1/16 to 2 mm grain size except 2 cores which are made from <1/16 mm and >2 mm grain size. As mentioned in the previous table and section of this chapter that quartzarenites (quartzite) have 1/16 to 2 mm grain size, chert have <1/16 mm grain size and chert breccia having >2 mm grain size. Therefore, quartzarenites (quartzite) with 1/16 to 2 mm grain size where the most preferred raw material (Table 4.13.2).

Table 4.13.2. Frequency of flaked piece by grain size types from Benkaneri.

Flaked piece		Grain Size of Raw Material			Total
		<1/16 mm	**>2 mm**	**1/16 to 2 mm**	
Large Cutting Tools	Handaxe	0 (0.00)	0 (0.00)	9 (100)	9 (23.6)
	Axe Blank	0 (0.00)	0 (0.00)	4 (100)	4 (10.5)
	Cleaver	0 (0.00)	0 (0.00)	1 (100)	1 (2.6)
	Cleaver Blank	0 (0.00)	0 (0.00)	1 (100)	1 (2.6)
	Pick	0 (0.00)	0 (0.00)	3 (100)	3 (7.9)
Chopper	Bifacial Chopper	0 (0.00)	0 (0.00)	1 (100)	1 (2.6)
Cores	Bidirectional	0 (0.00)	0 (0.00)	1 (100)	1 (2.6)
	Multi-Platform	1 (7.7)	1 (7.7)	11 (84.6)	13 (34.2)
Retouched Tool	Concave Side Scraper	0 (0.00)	0 (0.00)	2 (100)	2 (5.3)
	Notched Tool	0 (0.00)	0 (0.00)	3 (100)	3 (7.9)
Total		**1**	**1**	**36**	**38**

4.14. General metrical measurements for flaked piece types

Several important attributes were recorded in order to explain the variability within the flake piece type common metrical attributes like maximum dimension, maximum width and thickness were recorded in order to measure the shape and size of flaked piece. From Table 4.14.1., it is easy to explain that the large cutting tools were longer (122.6 mm) and wider (81.07 mm) than any other flaked piece (Figure 4.14.1). When thickness is considered core were thicker (53.3 mm) than large cutting tools (47.97 mm) and retouched tool (15.32 mm) types (Figure 4.14.2). The tables and figures also suggest that the retouched tools were the shortest, narrowest and thinnest among all other flaked piece types and retouched tools were the flaked piece type which shows more variation (CV- maximum dimension (0.45), maximum width (0.31) and thickness (0.43)) within them.

Table 4.14.1. Mean, standard deviation and coefficient of variation of flaked piece types from Benkaneri.

Flaked Piece	Variable	Mean	Std. Deviation	CV
LCT's	Maximum Dimension	122.6	40.79	0.33
	Maximum Width	81.07	22.54	0.28
	Thickness	47.97	13.08	0.27
Core	Maximum Dimension	90.55	20.61	0.23
	Maximum Width	79.55	16.04	0.2
	Thickness	53.3	9.2	0.17
Retouched	Maximum Dimension	60.83	27.67	0.45
	Maximum Width	46.47	14.18	0.31
	Thickness	15.32	6.56	0.43

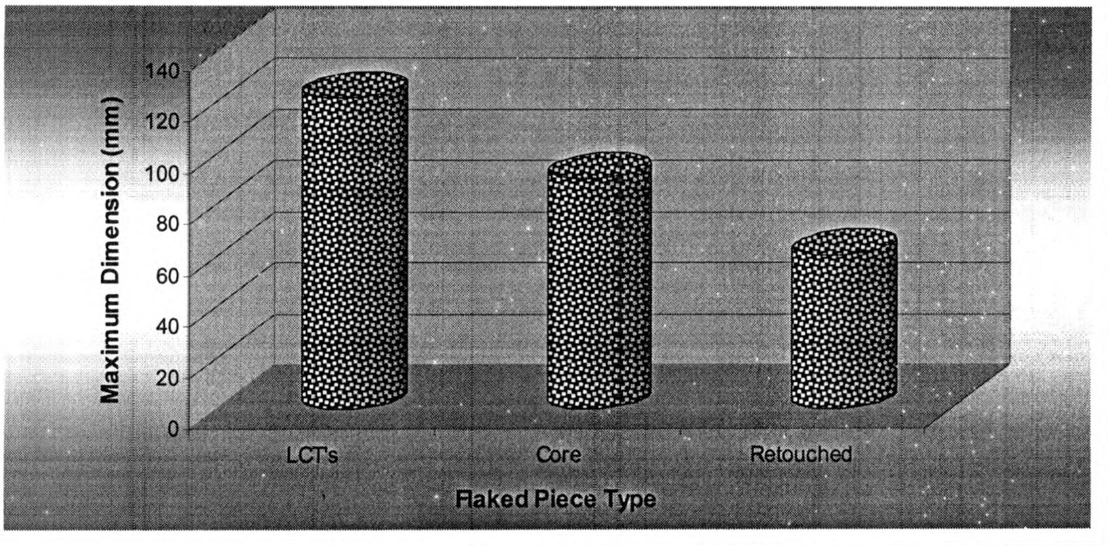

Figure 4.14.1. Bar graph of maximum dimension for flaked piece types from Benkaneri.

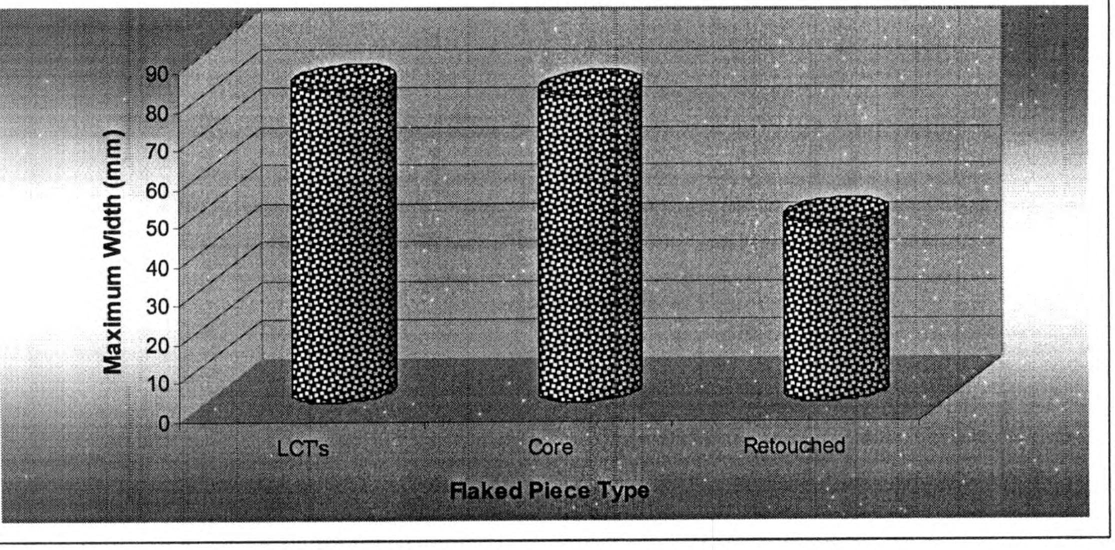

Figure 4.14.2. Bar graph of maximum width for flaked piece types from Benkaneri.

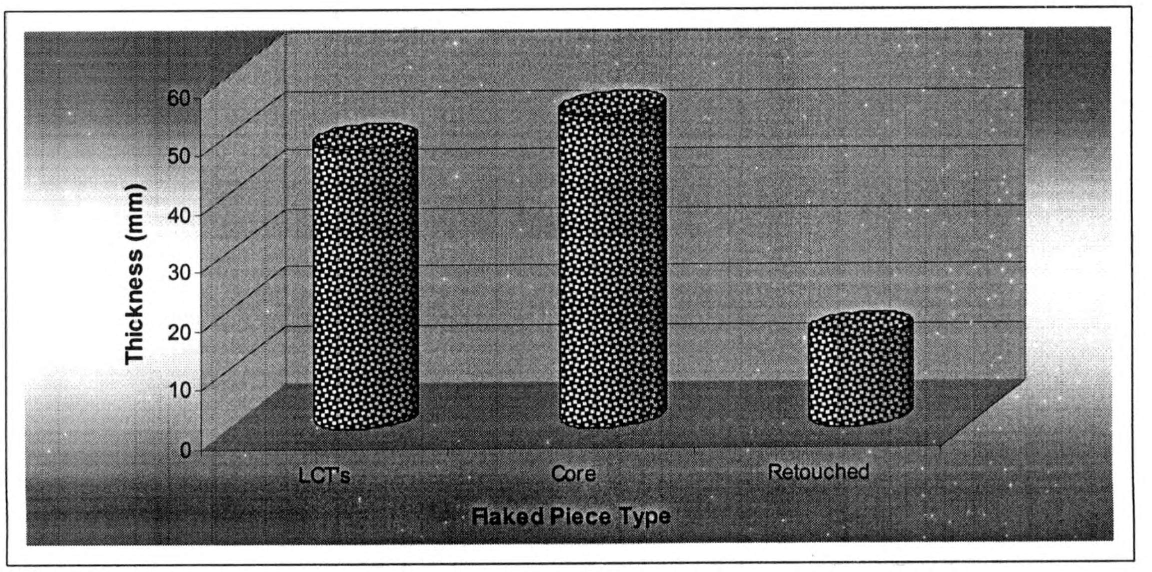

Figure 4.14.3. Bar graph of thickness for flaked piece types from Benkaneri.

4.15. Accessing variability within the flaked piece types

In order to explain the variability as observed from the comparison made within the flake piece types with its metrical measurements, this variability in flaked piece type will be explained with the help of variability in raw material (types, size and shape), initial form and cortex types.

Variability in raw material to explain the variability in flaked piece types

When these attributes of flaked piece were compared with the raw material types, it showed that large cutting tools made from quartzarenites (quartzite) were the longest and widest flaked piece. Majority of cores were made from quartzarenites (quartzite), except two which were made from chert and chert breccia. The cores which are made from quartzarenites (quartzite) were the longest, widest and thickest, followed by chert breccia and chert. All retouched tools which are made from quartzarenites (quartzite) are the shortest, narrowest and thinnest among all other flaked piece.

Table 4.15.1. Mean, standard deviation and coefficient of variation of flaked piece type by raw material types from Benkaneri.

Flaked Piece	Raw Material	Variable	Mean	Std. Deviation	CV
LCT's	Quartzarenites (quartzite)	Maximum Dimension	122.60	40.79	0.33
		Maximum Width	81.07	22.54	0.28
		Thickness	47.97	13.08	0.27
Core	Quartzarenites (quartzite)	Maximum Dimension	94.13	20.34	0.22
		Maximum Width	82.03	16.07	0.20
		Thickness	54.73	9.17	0.17
	Chert	Maximum Dimension	66.19	0	0
		Maximum Width	60.16	0	0
		Thickness	43.29	0	0
	Chert Breccia	Maximum Dimension	75.52	0	0
		Maximum Width	71.71	0	0
		Thickness	46.19	0	0
Retouched	Quartzarenites (quartzite)	Maximum Dimension	60.83	27.67	0.45
		Maximum Width	46.47	14.18	0.31
		Thickness	15.32	6.56	0.43

The above information clearly shows the preference of the raw material types as well as the variability within the flaked piece types on the same raw material types and with respect to the shape and size, large cutting tools made on quartzarenites (quartzite) were the longest among all flaked piece types, whereas, cores made on the same raw material type were wider and thicker than the large cutting tools and the retouched tools. The retouched tool types were found made on this type of raw material (quartzarenites) are the smallest, widest and thinnest than the other flaked piece types.

Variability in* Initial form *to explain the variability in flaked piece types

Initial form of the flaked piece types also shows the variability in the respective the initial form was recorded on the only flaked piece type like large cutting tools. Table 4.15.2, show that flaked piece made from blocky were longer, wider and thicker, whereas, flaked piece made from cobbles were shorter, but when the width and thickness is taken into account flaked piece made from flake were narrower and thinner.

Table 4.15.2. Mean, standard deviation and coefficient of variation of flaked piece type by initial form types from Benkaneri.

Initial Form	Variable	Mean	Std. Deviation	CV
Blocky	Maximum Dimension	141.82	0	0
	Maximum Width	94.58	0	0
	Thickness	74.98	0	0
Cobble	Maximum Dimension	115.08	25.16	0.22
	Maximum Width	86.16	5.39	0.06
	Thickness	59.99	12.05	0.20
Flake	Maximum Dimension	125.60	29.14	0.23
	Maximum Width	85.65	25.74	0.30
	Thickness	43.76	9.80	0.22
Indeterminate	Maximum Dimension	120.39	57.26	0.48
	Maximum Width	73.46	24.61	0.34
	Thickness	43.78	10.59	0.24

Variability in cortex types to explain the variability in flaked piece types

Out of 19 large cutting tools 8 had cortex type information and others were completely flaked all over. From these 8, 5 were made on angular clast and other 3 were made from sub-angular, sub-rounded and indeterminate. Because of low count of these clast types (i.e., sub-angular, sub-rounded and indeterminate) they were excluded for further analysis, but if these cortex types which had low count is considered, then, the large cutting tools that were made from sub-angular are longer and are wider, whereas large cutting tools made from sub-rounded clast are thickest among all. From 14 cores, 12 had information on the cortex type and 2 had no information on the cortex type. Out of these 12 cores which had cortex type information, 7 were made from angular clast and 3 were included in the indeterminate group because of its minimum cortex information and remaining 2 cores were made from sub-angular and sub-rounded clast type. If these two clasts namely sub-angular and sub-rounded of the cores, which has lower count, were included, then the cores which are made from sub-angular clast were longest, widest and thickest than those were made on sub-rounded and retouched tools had no information on the cortex types (Table 4.15.3).

Table 4.15.3. Mean, standard deviation and coefficient of variation of flaked piece type by cortex types from Benkaneri.

Flaked Piece Type	Cortex Type	Variable	Mean	Std. Deviation	CV
LCT's	Angular	Maximum Dimension	115.21	18.99	0.16
		Maximum Width	77.20	12.06	0.16
		Thickness	48.61	15.33	0.32
	Sub-Angular	Maximum Dimension	142.38	0	0
		Maximum Width	85.68	0	0
		Thickness	60.37	0	0
	Sub-Rounded	Maximum Dimension	110.03	0	0
		Maximum Width	91.78	0	0
		Thickness	71.85	0	0
	Indeterminate	Maximum Dimension	65.1	0	0
		Maximum Width	48.1	0	0
		Thickness	35.37	0	0
	Absent	Maximum Dimension	130.53	48.67	0.37
		Maximum Width	84.43	26.72	0.32
		Thickness	45.53	10.91	0.24
Core	Angular	Maximum Dimension	94.95	25.47	0.27
		Maximum Width	84.22	19.01	0.23
		Thickness	54.17	9.39	0.17
	Sub-Angular	Maximum Dimension	110.9	0	0
		Maximum Width	77.84	0	0
		Thickness	70.79	0	0
	Sub-Rounded	Maximum Dimension	59.88	0	0
		Maximum Width	54.36	0	0
		Thickness	46.45	0	0
	Indeterminate	Maximum Dimension	85.91	12.49	0.15
		Maximum Width	74.07	12.29	0.17
		Thickness	53.72	4.87	0.09
	Absent	Maximum Dimension	89.45	1.56	0.02
		Maximum Width	87.21	1.39	0.02
		Thickness	44.33	2.21	0.05
Retouched	Absent	Maximum Dimension	60.83	27.67	0.45
		Maximum Width	46.47	14.18	0.31
		Thickness	15.32	6.56	0.43

4.16. Large cutting tool types at Benkaneri

This section will qualitatively and quantitative explore large cutting tools by analyzing its size and shape. Common metrical and non-metrical measurements are analyzed within and between the large cutting tool types. Shape defines measurements and ratios are also analyzed.

From a total of 125 artifacts collected, 19 were large cutting tools, among these large cutting tools, 14 are complete and 5 were broken. Out of 19 large cutting tools, 8 (42.1%) are handaxe, 5 (26.3%) are axe blank, 3 (15.8%) are picks, 2 (10.5%) are cleavers and 1 (5.3%) chopper (Table 4.16.1).

Table 4.16.1. Frequency of large cutting tool types from Benkaneri.

Large Cutting Tool Type	Frequency	Percent
Handaxe	8	42.1
Cleaver	2	10.5
Axe Blank	5	26.3
Chopper	1	5.3
Pick	3	15.8
Total	**19**	**100**

All large cutting tools that were collected from this site were made from quartzarenites (quartzite) and this made it impossible to explore the effect of raw material on assemblage variability.

4.17. Non-metrical attributes recorded for large cutting tools

Common non-metrical attributes were recorded for large cutting tools (non-metrical are explained in the previous section as well as in the methodology section of this thesis). Simple bar, box plots and simple tables were used in order to explain these non-metrical attributes.

Cortex type

From 14 complete large cutting tools only 7 (50%) had the information on the cortex type. **Majority of large cutting tools were made on angular (5) followed by sub-angular (1) and sub-rounded (1).** Out of these 7 large cutting which had information, 1 (14.3%) was handaxe, 3 (42.8%) were axe blank, 2 (28.6%) were pick and 1 (14.3%) was chopper (Table 4.17.1).

Table 4.17.1. Cortex type for large cutting tool types from Benkaneri.

Large Cutting Tool Type	Cortex Type			Total
	Angular	Sub-Angular	Sub-Rounded	
Handaxe	1 (20)	0 (0.00)	0 (0.00)	1 (14.3)
Axe Blank	2 (40)	1 (100)	0 (0.00)	3 (42.8)
Chopper	0 (0.00)	0 (0.00)	1 (100)	1 (14.3)
Pick	2 (40)	0 (0.00)	0 (0.00)	2 (28.6)
Total	**5 (71.4)**	**1 (14.3)**	**1 (14.3)**	**7**

Handaxe which had the information on the cortex type was made from angular clast type and others like axe blank were made from 2 angular and 1 sub-angular clast type. Both the picks were made on angular and chopper was the only one of the large cutting tool type which was made on sub-rounded clast type.

Initial form

These initial forms were recorded in order to understand the preference by the hominins at this site. Three types of initial forms were recorded from this site, from which the hominins were manufacturing these large cutting tools and they are blocky, cobble and flake types.

Table 4.17.2. Large cutting tools broken down by its initial form from Benkaneri.

Large Cutting Tool Type	Blocky	Cobble	Flake	Indeterminate	Total
Handaxe	0 (0.00)	0 (0.00)	3 (75)	1(25)	4 (28.6)
Axe Blank	0 (0.00)	1 (25)	2 (50)	1(25)	4 (28.6)
Cleaver	0 (0.00)	0 (0.00)	1 (50)	1 (50)	2 (14.3)
Pick	1 (33.3)	1 (33.3)	0 (0.00)	1 (33.3)	3 (21.4)
Chopper	0 (0.00)	1 (100)	0 (0.00)	0 (0.00)	1 (7.1)
Total	**1 (7.1)**	**3 (21.4)**	**6 (42.8)**	**4 (28.6)**	**14**

Table 4.17.2., is a tabulation for complete large cutting tool types by its initial form. Proportions are in parentheses in row; whereas, total of large cutting tool is in column wise. From the Table 4.17.2., it is clear **that the majority of large cutting tools were made from flakes (6), followed by indeterminate (4), cobble (3) and blocky (1).** As said before handaxes were 4 in number and these handaxe were made from 3 flakes and 1 on indeterminate. 4 of these axe blanks were made on 2 flakes, 1 on cobble and 1 on indeterminate. Cleavers were made on flake and indeterminate. 3 picks which were collected were made on 1 blocky, 1 on cobble and 1 on indeterminate; whereas, the chopper which is the least in count was made on cobble.

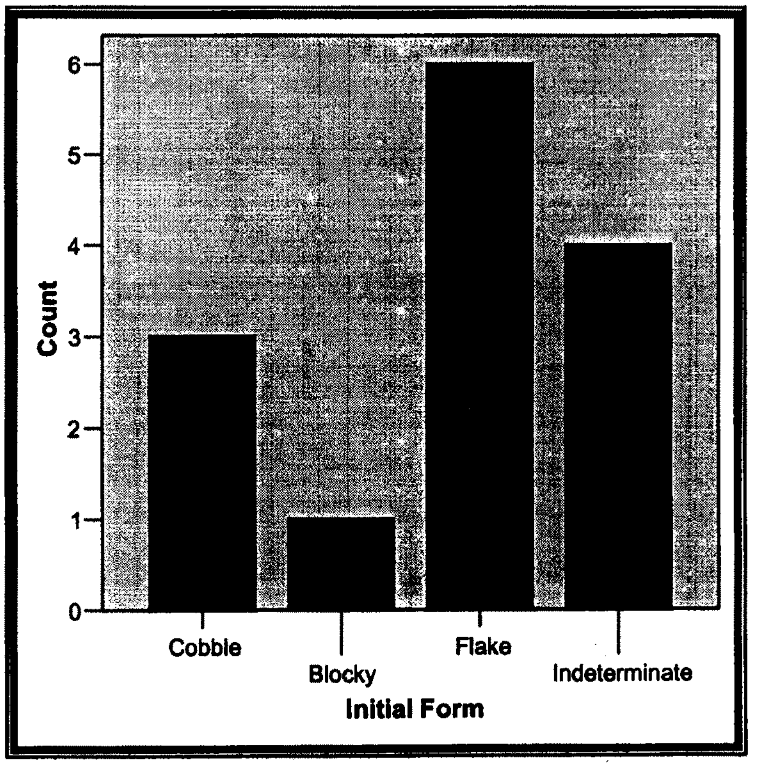

Figure 4.17.1. Bar graph of initial form for large cutting tool from Benkaneri.

Breakage pattern in large cutting tools

Among 19 large cutting tools, 6 (31.5%) had broken tip or butt end. Out of these 6, 4 large cutting tools broke at the tip portion and they were from handaxe (3) and axe blanks (1) (Table 4.17.3). Whereas, 2 large cutting tool broke at the butt end and that is from axe blank. This shows that the hominins at this site committed error while they were reducing the lateral margin or at the butt end because the majority

of them were snapouts, in which tip is broken, this occurred due to excessive pressure or wrong blow given to the butt end or on the lateral margin.

Table 4.17.3. Large cutting tools broken down by its breakage pattern from Benkaneri.

Breakage	Large Cutting Tool Type		Total
	Handaxe	Axe Blank	
Tip is broken	3	0	3
Buttend is broken	1	2	3
Total	4	2	6

Tip shape of large cutting tool

This variable was recorded in order to visualize the shape of the tip of large cutting tools, because every large cutting tool had its own tip shape and they are quite different from each other (e.g., cleavers tip shape is different from handaxe and within each type itself variation in tip shape could be noticed).

Table 4.17.4. Large cutting tools broken down by its tip shape from Benkaneri.

Tip Shape	Large Cutting Tool Type					Total
	Handaxe	Cleaver	Axe Blank	Chopper	Pick	
A type	4	0	2	0	2	8
C type	1	0	2	0	0	3
D type	0	1	0	0	1	2
F type	0	1	0	0	0	1
G type	0	0	0	1	0	1
Total	**5**	**2**	**4**	**1**	**3**	**15**

Table 4.17.4., provides tabulation for large cutting tool types and its tip shape. Out of 19 large cutting tools collected from the site Benkaneri, 15 had information on the tip shape. From these 15, 8 large cutting tools had markedly convergent tip shape, 3 had markedly convergent with a squared off tip and a clearly oblique shaped tip, 2 had markedly convergent with a generalized tip, 1 has a broad tip with right angle, having divergent or parallel/sub-parallel sides at the cutting edge of the tool and with a wide tip at a markedly oblique angle to the long axis and remaining 1 has wide with a very convex tip and without any break in the convexity. Among 19 large cutting tools, 5 of them were handaxe, in which 4 had 'A type' tip shape (i.e., markedly convergent tip) and 1 had 'C type' (i.e., markedly convergent with a squared off tip and a clearly oblique shaped tip) and this was followed by 4

axe blanks, with 2 'A type' as well as 2 'C type' tip shapes, in which the former has markedly convergent tip and latter with markedly convergent squared off tip and a clearly oblique shaped tip. The next dominating tool type was the pick, which is totally 3 in numbers with 2 'A type' and 1 'D type'. Remaining tool categories are cleaver (2) and chopper (1), in which cleavers had 'D' and 'F type' tip shapes respectively, whereas chopper with 'G type' tip shape (i.e., wide with convex tip).

Cross Section of large cutting tools

Out of 19 large cutting tools, 15 gave cross section information at this site. From these 15, 9 (60%) large cutting tools have biconvex cross section, 3 (20%) has lenticular, 2 (13.3%) with high back and 1 (6.6%) has parallelogram cross section.

Table 4.17.5. Cross section of large cutting tools from Benkaneri.

Cross Section	Frequency	Percent
Biconvex	9	60
Lenticular	3	20
Parallelogram	1	6.6
High Back	2	13.3
Total	**15**	**100**

As said above, 15 large cutting tools had the information on cross section. Out of these 15, 5 were handaxe, 5 axe blank, 3 pick and 2 cleavers. Handaxes which are 5 in numbers, had 4 biconvex and 1 lenticular cross section. Then comes, 5 axe blanks, having 2 biconvex and 1 lenticular, 1 parallelogram and 1 high back cross section. Among 3 picks, 2 have biconvex and 1 has high back cross section. The last tool type, cleaver, which has 1 biconvex and 1 lenticular cross section. Thus Table 4.17.5. and 4.17.6., indicates that majority of large cutting tool have biconvex and lenticular cross section, because they were bifacially reduced from angular clasts type.

Table 4.17.6. Large cutting tool types broken down by its cross section from Benkaneri.

Large Cutting Tool Type	Cross Section				Total
	Biconvex	Lenticular	Parallelogram	High Back	
Handaxe	4 (80)	1 (20)	0 (0.00)	0 (0.00)	5 (33.3)
Cleaver	1 (50)	1 (50)	0 (0.00)	0 (0.00)	2 (13.3)
Axe Blank	2 (40)	1 (20)	1 (20)	1 (20)	5 (33.3)
Pick	2 (66.6)	0 (0.00)	0 (0.00)	1 (33.3)	3 (20)
Total	**9**	**3**	**1**	**2**	**15**

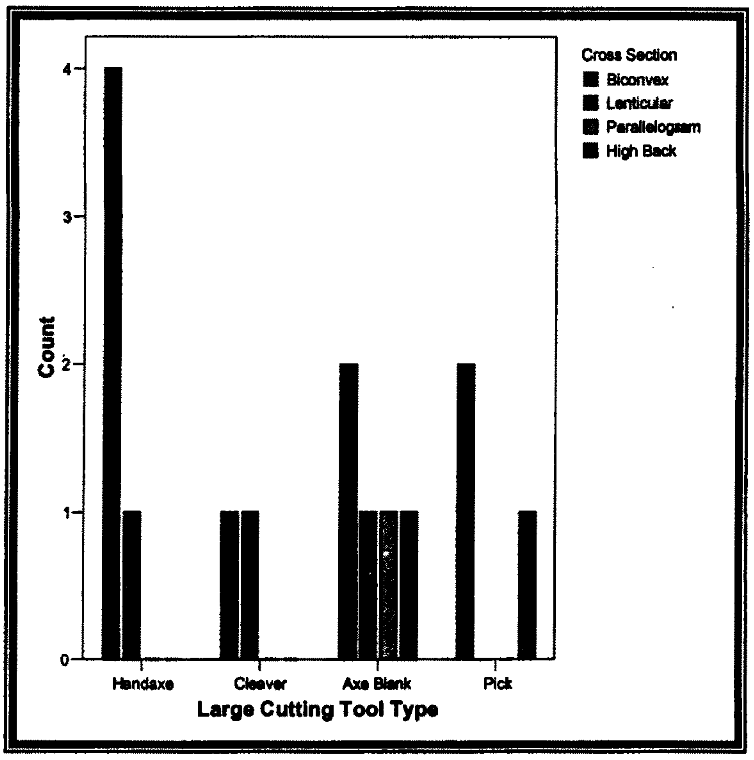

Figure 4.17.2.. Bar graph for large cutting tools types by its cross section from Benkaneri.

Profile form for large cutting tools

All 19 large cutting tools that was collected from the site Benkaneri had information on profile form, out of this 19, 15 of them have irregular, 2 have regular and 2 has straight profile form.

Table 4.17.7. Profile form types for large cutting tools from Benkaneri.

Profile Form	Frequency	Percent
Straight	2	10.5
Regular	2	10.5
Irregular	15	78.9
Total	19	100

Out of these 19 large cutting tools, 8 were handaxes, 5 were axe blanks, 3 were picks, 2 were cleaver and 1 was chopper. (1) have irregular profile form. Handaxes which are 8 in numbers, had 6 irregular, 1 regular and 1 straight profile form. Then comes, 5 axe blanks, having 4irregular and 1 straight profile form (Table 4.17.7). All 3 picks had irregular profile form and whereas, cleaver has 1 regular and 1 irregular profile form and 1 chopper has irregular profile form (Table 4.17.8).

Table 4.17.8. Large cutting tool types broken down by its profile form from Benkaneri.

Large Cutting Tool Type	Profile Form			Total
	Straight	Regular	Irregular	
Handaxe	1	1	6	8
Cleaver	0	1	1	2
Axe Blank	1	0	4	5
Chopper	0	0	1	1
Pick	0	0	3	3
Total	**2**	**2**	**15**	**19**

4.18. General metrical attributes recorded for large cutting tools

General attributes like maximum dimension, maximum width, thickness and weight were recorded in order to explain the size and shape of large cutting tools from Benkaneri. Mean, standard deviation and coefficient of variation values and simple plots (bar, line, histogram, box and scatter) were applied in order to explain the variability within large cutting tool's size and shape.

Large cutting tools were classified as handaxes, axe blank, cleaver, pick and choppers. Handaxes (8) were the majority of large cutting tool type, at this site, which was followed by axe blanks (5), pick (3), cleaver (2) and chopper (1). Chopper is excluded for further statistical analysis because of small sample size (>2).

Large cutting tools from Benkaneri vary considerably in size and shape, as explained by mean, standard deviation and coefficient of variation for general metrical measurements (Table 4.18.1). Large cutting tool vary in length (98.62 - 177.90 mm), width (61.79-113.20 mm), thickness (38.33-63.66 mm) and weight (282.93-1109.25 mm). Table 4.18.1 and Figure 4.18.1 to 4.18.4., provides a box plot of maximum dimension for all large cutting tools. Handaxe (242.46 mm) have greater maximum dimensions than all other large cutting tools. Cleavers (184.92 mm) are the second largest large cutting tool type and it is followed by axe blank (142.38 mm) and picks (141.82 mm), which are the smallest among all the large cutting tools.

Large cutting tool length varies considerably (CV=0.27) between large cutting tools with the longest large cutting tool. Longest large cutting tool are

cleavers and shortest are pick (111.69±26.37 mm). Standard deviation and coefficient of variation indicates significant variability in large cutting tool types. Cleavers tend to be longer than any other large cutting tools. Large cutting tools breadth (maximum width) varies considerably (CV=0.26) between large cutting tool. Widest large cutting tools are cleavers (113.33±35.31 mm) and narrowest large cutting tool is handaxe (75.27±21.94mm). Thickness varies considerably (CV=0.23) between large cutting tool. The thickest large cutting tool from Benkaneri is pick (58.30±14.61 mm) and the thinnest is handaxe (42.06±8.91 mm). Weight also varies considerably (CV=0.718) between large cutting tools at Benkaneri. Heaviest large cutting tool are the cleavers (1026.50±634.27 gms) and the lights are axe blanks (407.72±193.95 gms).

Table 4.18.1. Mean, minimum, maximum, standard deviation and coefficient of variation of general metrical measurements of large cutting tool types from Shankaragatta.

Variable	Type	Mean	Minimum	Maximum	Std. Deviation	CV
Maximum Dimension	Handaxe	118.55	65.1	242.46	56.72	0.48
	Axe Blank	123.26	101.93	142.38	18.48	0.15
	Cleaver	159.78	134.64	184.92	35.55	0.22
	Pick	111.69	92.82	141.82	26.37	0.24
	Total	128.32	98.62	177.90	34.28	0.27
Maximum Width	Handaxe	75.27	48.1	121.23	21.94	0.29
	Axe Blank	76.10	47.15	98.69	19.01	0.25
	Cleaver	113.33	88.36	138.3	35.31	0.31
	Pick	79.72	63.54	94.58	15.56	0.20
	Total	86.10	61.79	113.20	22.96	0.26
Thickness	Handaxe	42.06	32.42	56.4	8.91	0.21
	Axe Blank	43.65	26.04	60.37	12.36	0.28
	Cleaver	55.01	47.12	62.89	11.15	0.20
	Pick	58.30	47.75	74.98	14.61	0.25
	Total	49.75	38.33	63.66	11.76	0.24
Weight	Handaxe	427.69	125.1	1425	432.06	1.01
	Axe Blank	407.72	160.6	630	193.95	0.48
	Cleaver	1026.50	578	1475	634.27	0.62
	Pick	484.00	268	907	366.36	0.76
	Total	586.48	282.93	1109.25	406.66	0.72

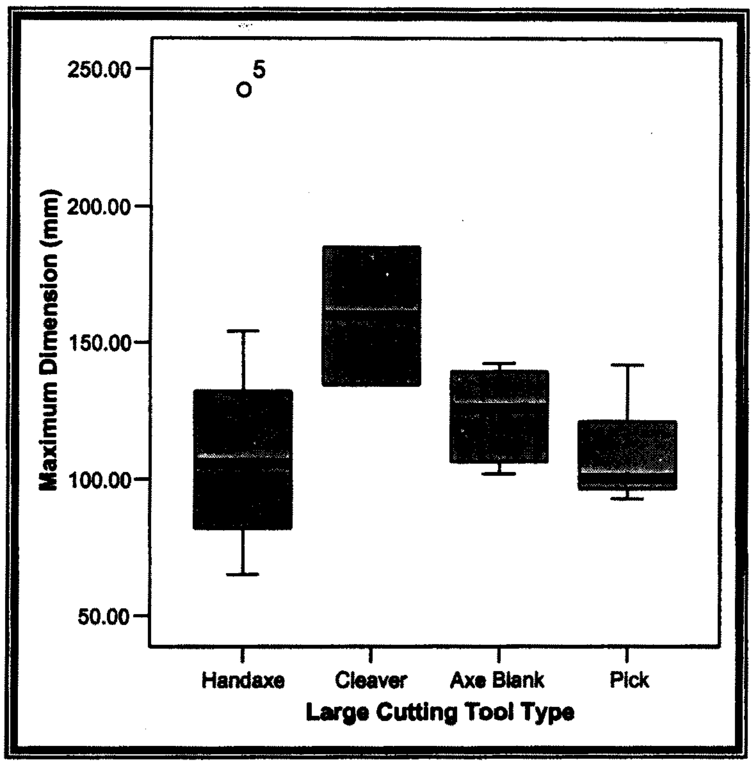

Figure 4.18.1. Box plot of maximum dimension for flaked piece types from Benkaneri. Circles represent extremes.

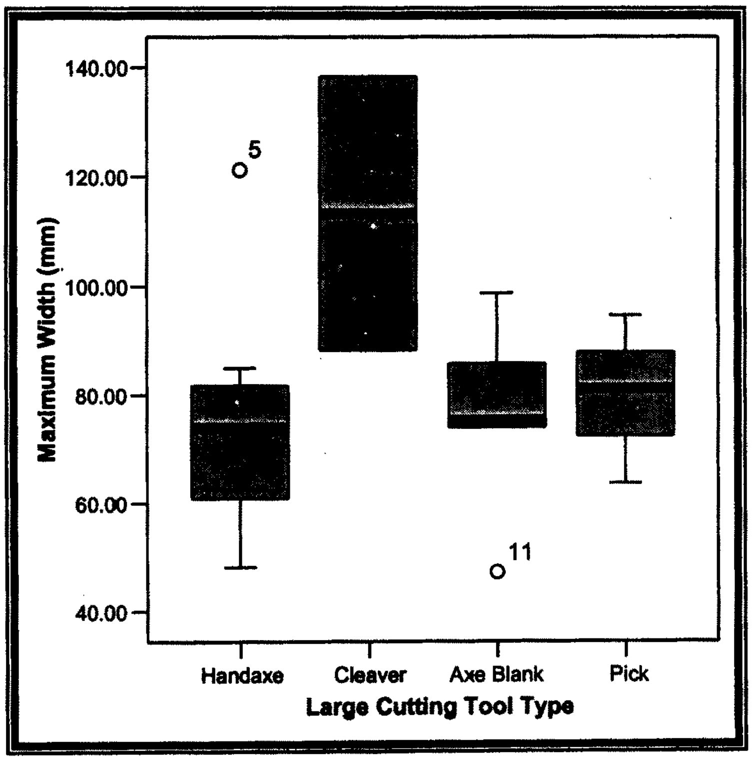

Figure 4.18.2. Box plot of maximum width for flaked piece types from Benkaneri. Circles represent extremes.

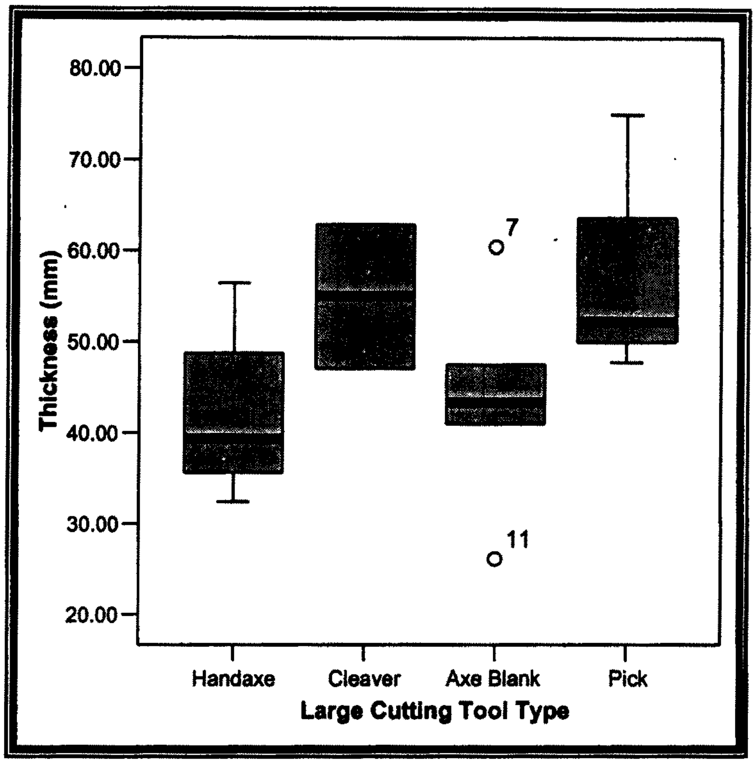

Figure 4.18.3. Box plot of thickness for flaked piece types from Benkaneri. Asterisks represent outliers.

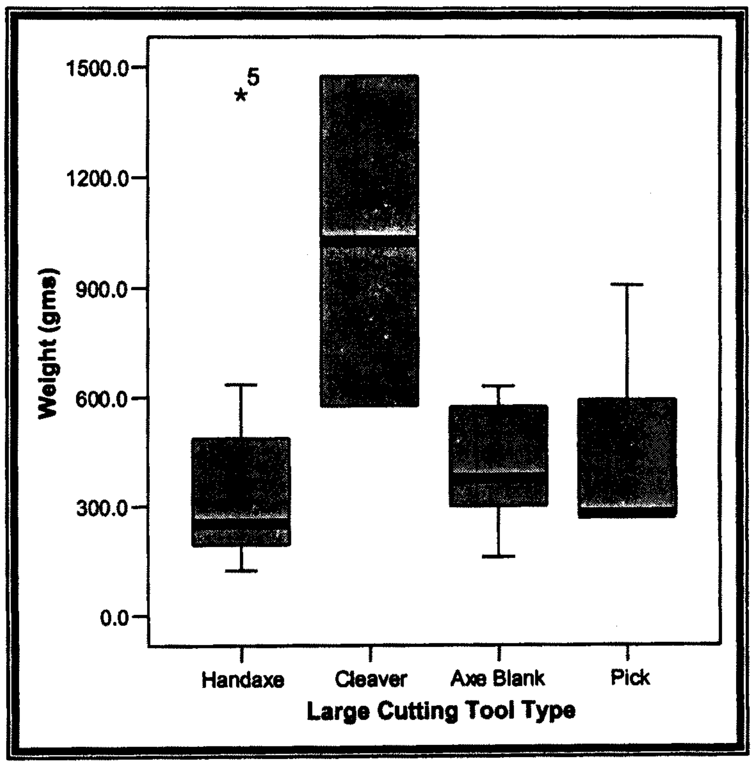

Figure 4.18.4. Box plot of weight for flaked piece types from Benkaneri. Asterisks represent outliers.

Correlation between general metrical attributes recorded for large cutting tools.

A bivariate correlation test was intended in order to find out the relationship within and between the general linear measurements, and the results are as following:

From the Table 4.18.2., it is clear that maximum dimension, maximum width, thickness and weight of the large cutting tools have a significant correlation at 0.01 level (significantly different)and the positive Pearson Correlation indicates that, as the maximum dimension value increases, other variables (maximum width and weight) value also increases. When the thickness is compared with maximum dimension, the correlation was significant at 0.05 levels with lesser values of Pearson Correlation.

From the above table and from its description it can be summarized that the bivariate correlation test revealed interesting aspects of the large cutting tools and they are:

- Linear measurements for shape/morphology and size of large cutting tools like maximum dimension, maximum width, thickness and weight showed an increase in the value when it was compared within the group itself along with the positive Pearson Correlation value.

Table 4.18.2. Bivariate correlation test result within and between large cutting tools general linear attributes. All general linear attributes which are significant at 0.01 level are in blue colour and 0.05 level in red colour. The attribute which are significant in 2-tailed level are marked in bold.

Correlations					
Variable	**Correlation**	**Maximum Dimension**	**Maximum Width**	**Thickness**	**Weight**
Maximum Dimension	Pearson Correlation	1	0.833	0.506	0.897
	Sig. (2-tailed)	.	**0.000**	0.027	**0.000**
	N	19	19	19	19
Maximum Width	Pearson Correlation	0.833	1	0.672	0.937
	Sig. (2-tailed)	**0.000**	.	0.002	**0.000**
	N	19	19	19	19
Thickness	Pearson Correlation	0.506	0.672	1	0.719
	Sig. (2-tailed)	0.027	0.002	.	0.001
	N	19	19	19	19
Weight	Pearson Correlation	0.897	0.937	0.719	1
	Sig. (2-tailed)	**0.000**	**0.000**	0.001	.
	N	19	19	19	19

The above description of table and box plot shows that, cleavers are the longest, widest, thickest and heaviest large cutting tool type. While picks are shorter than other large cutting tool types, whereas, handaxes are the narrowest and thinnest than any other tool types. The lightest tool among all types are axe blank. Bivariate correlation test also explain that as the maximum dimension increases maximum width and weight increases with a significant values.

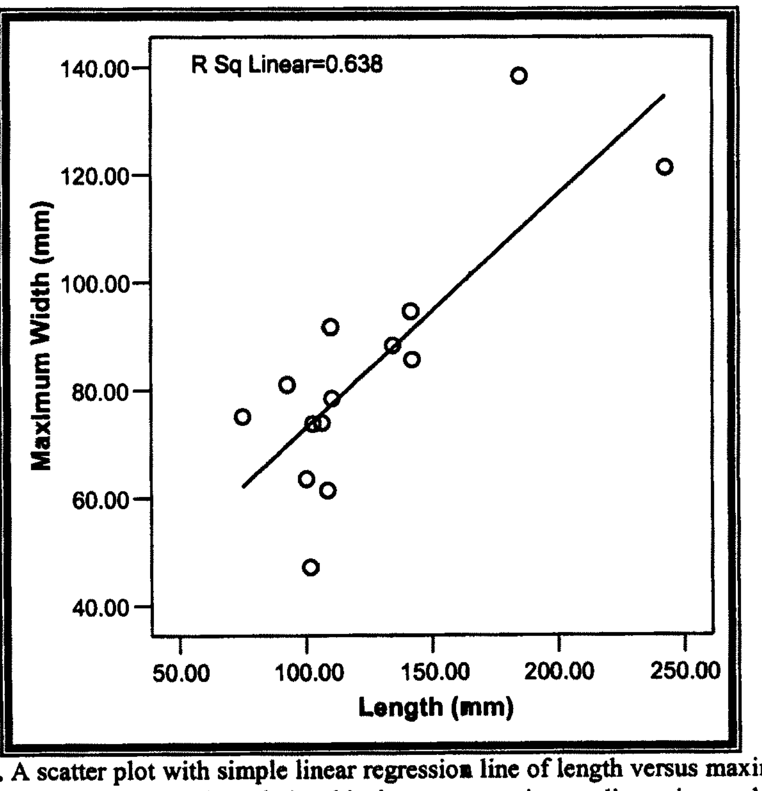

Figure 4.18.5. A scatter plot with simple linear regression line of length versus maximum width for large cutting tools from Benkaneri. The relationship between maximum dimension and maximum width is reasonably isometric.

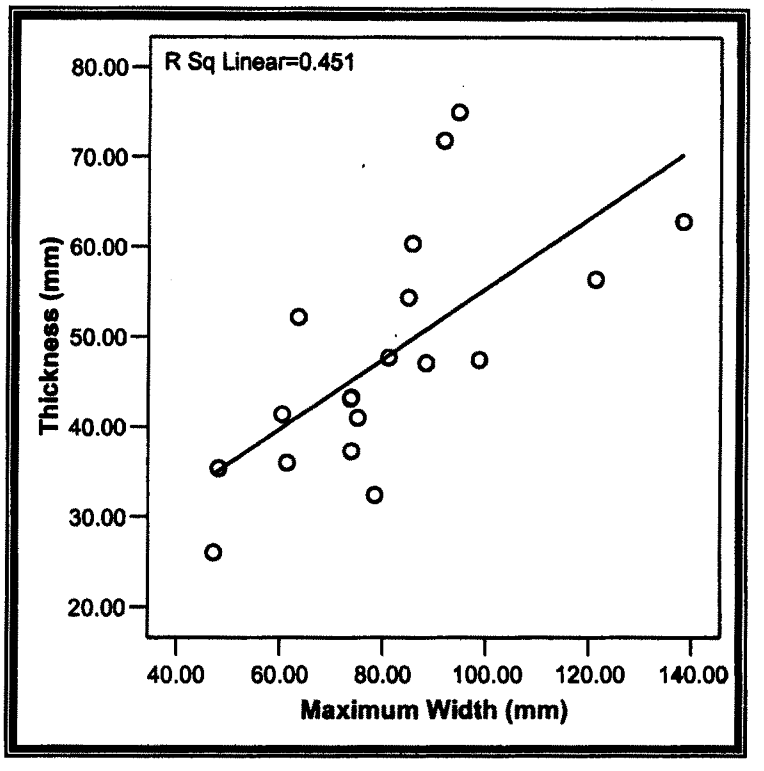

Figure 4.18.6. A scatter plot with simple linear regression line of maximum width versus thickness for large cutting tools from Benkaneri. The relationship between maximum width and thickness is reasonably isometric.

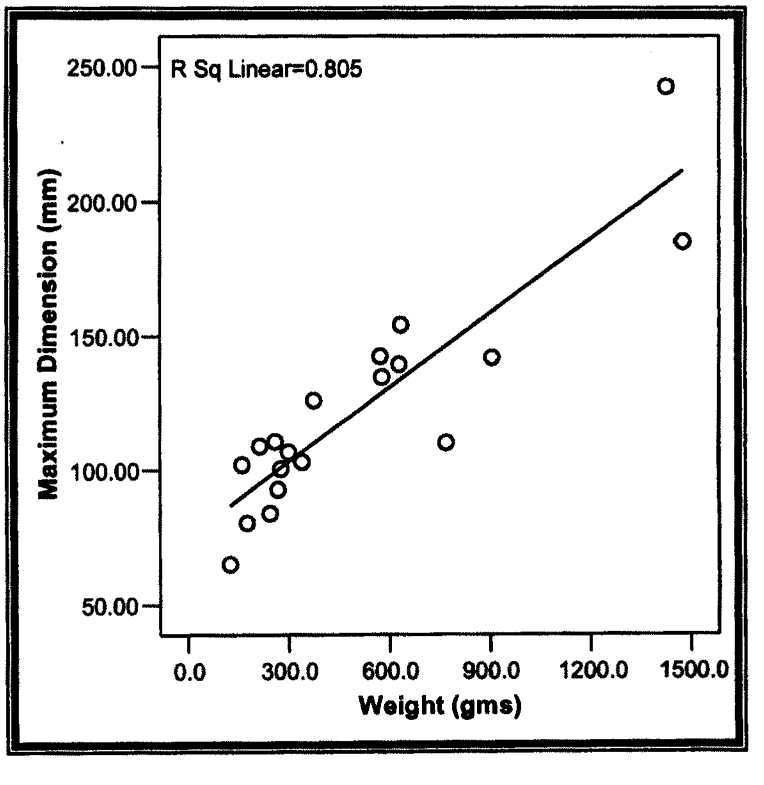

Figure 4.18.7. A scatter plot with simple linear regression line of weight versus maximum dimension for large cutting tools from Benkaneri. The relationship between maximum width and thickness is reasonably isometric.

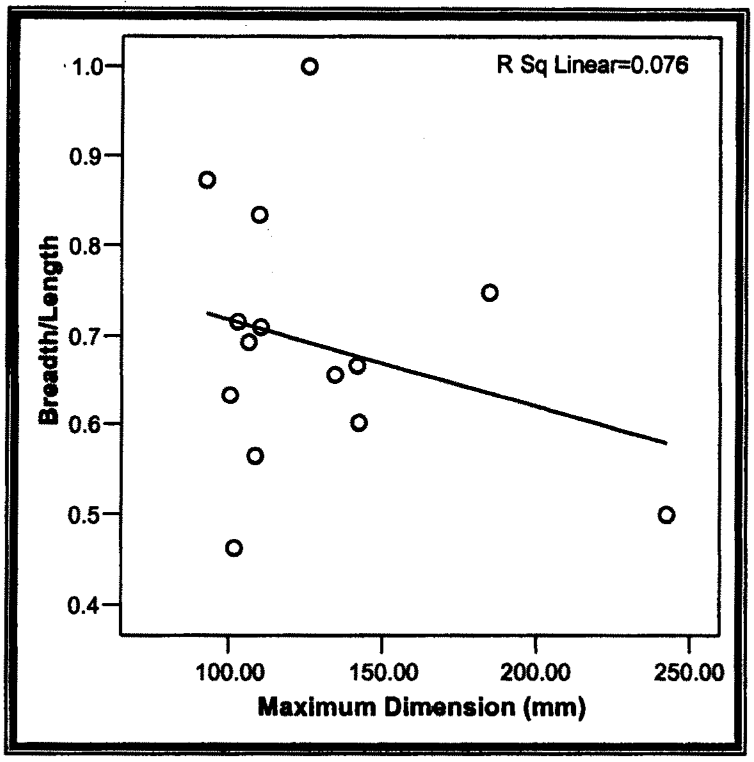

Figure 4.18.8. A scatter plot with simple linear regression line of maximum dimension versus edge shape index ratio (breadth/length) for large cutting tools from Benkaneri. The relationship between maximum width and thickness is reasonably isometric.

Length versus maximum width has an isometric relationship within Benkaneri large cutting tools (Figure 4.18.5). Figure 4.18.5., shows that when length increases maximum width also increases. Maximum width versus thickness also shows an isometric relationship within the large cutting tools (Figure 4.18.6) and this isometric relation shows that, as the maximum width increases thickness also increases. The allometry of large cutting tools is best expressed in Length versus shape index (B/L). Breadth/Length ratio provides a measure of narrow versus broad large cutting tools relative to length (Roe 1964, 1968). Figure 4.18.8., is a plot of mean length versus mean breadth/length for large cutting tools from Benkaneri. Large cutting tool with higher mean lengths tend to be proportionally narrower, while large cutting tool with lower mean length are proportionally broader.

4.19. Additional measurements for measuring size and shape of large cutting tool

Additional measurements for shape/morphological measures of large cutting tools were taken. Table 4.19.1., provides the mean, minimum, standard deviation and coefficient of variation of tip width (B1), mid width (B2), base width (B3), tip thickness (T1), mid thickness (T2), base thickness (T3), base length and tip length of

the large cutting tools. Cleavers are excluded from this analysis due to their low counts in the collection.

Tip width of the large cutting tools varies considerably (CV=0.23) between the large cutting tool types. Broadest tip width for large cutting tool was of axe blanks and narrowest was for pick (27.60±0.09mm). Like wise mid width of large cutting tools also vary considerably (CV=0.21) between large cutting tools, and this mid width is often seen wider in handaxes, but picks have the narrowest mid width value (56.60±3.26 mm). Base width value of large cutting tools was higher in pick and lower in axe blanks (59.08±11.78 mm).

Both tip and mid thickness value for pick is comparatively higher than other tool types, whereas handaxe was thinnest at its tip portion (16.09±6.86 mm) and axe blank were thinnest at its mid portion (36.91±10.36 mm). Picks are thicker and handaxes are thinner at its base than other tool types. Base length for picks are higher and lower in handaxe (52.35±20.40) and tip length of handaxe is higher than other tool types, while axe blanks has the lowest tip length.

Table 4.19.1. Mean, minimum, maximum, standard deviation and coefficient of variation of additional metrical measurements for large cutting tool types from Benkaneri.

Variable	Type	Mean	Std. Deviation	CV
Tip Width (B1)	Handaxe	34.23	10.74	0.31
	Axe Blank	36.18	10.54	0.29
	Pick	27.6	2.55	0.09
	Total	32.67	7.94	0.23
Mid Width (B2)	Handaxe	71.58	23.6	0.33
	Axe Blank	66.95	15.62	0.23
	Pick	56.6	3.26	0.06
	Total	65.04	14.16	0.21
Base Width (B3)	Handaxe	65.06	13.42	0.21
	Axe Blank	59.08	11.78	0.20
	Pick	65.08	19.51	0.30
	Total	63.07	14.90	0.24
Tip Thickness (Th1)	Handaxe	16.09	6.86	0.43
	Axe Blank	59.08	11.78	0.20
	Pick	65.08	19.51	0.30
	Total	46.75	12.72	0.31
Mid Thick (Th2)	Handaxe	38.64	12.29	0.32
	Axe Blank	36.91	10.36	0.28
	Pick	41.32	1.49	0.04
	Total	38.96	8.05	0.21
Base Thickness	Handaxe	32.84	5.73	0.17
	Axe Blank	36.59	8.44	0.23
	Pick	44.2	1.06	0.02
	Total	37.88	5.08	0.14
Base Length	Handaxe	52.35	20.4	0.39
	Axe Blank	53.17	8.6	0.16
	Pick	59.25	12.01	0.20
	Total	54.92	13.67	0.25
Tip Length	Handaxe	88.83	47.87	0.54
	Axe Blank	54.85	27.07	0.49
	Pick	61.87	17.27	0.28
	Total	68.52	30.74	0.44

The above table shows variations within tip width (B1), mid width (B2), base width (B3), tip thickness (T1), mid thickness (T2), base thickness (T3), base length and tip length of the large cutting tools. The value for Coefficient of variation in tip width (0.31), mid width (0.33), tip thickness (0.43), mid thickness (0.32), base length (0.39) and tip length (0.54) is higher in handaxe, indicative of more variations within the handaxe type, whereas the base width for picks (0.30) are higher and base thickness for axe blanks (0.23) are also higher.

These general measurements were then generated to define the edge shape, elongation and refinement for large cutting tools. Table 4.19.2., provides the mean, standard deviation and coefficient of variation values for these index.

Table 4.19.2. Mean, minimum, maximum, standard deviation and coefficient of variation of shape defining index ratios for large cutting tool types from Benkaneri.

Indices Defining Ratio	Types	Mean	Std. Deviation	CV
Edge Shape (B1/B3)	Handaxe	0.52	0.11	0.21
	Axe Blank	0.61	0.13	0.21
	Pick	0.44	0.09	0.20
Elongation (L/B)	Handaxe	1.64	0.29	0.18
	Axe Blank	1.57	0.48	0.31
	Pick	1.41	0.23	0.16
Refinement (B/T)	Handaxe	1.79	0.36	0.20
	Axe Blank	1.77	0.24	0.14
	Pick	1.39	0.26	0.19

Large cutting tool type's index ratios (breadthl/ breadth3, breadth/length, thickness/breadth and thickness1/thickness3) are quite variable. Breadth1/breadth3 ratios show that handaxe (CV=0.21) and axe blank (CV=0.21) are variable than pick (0.20). In elongation index axe blank show much variation (CV=0.31), whereas handaxe show variation (CV=0.20) in refinement. High mean value of B1/B3 ratio for axe blank indicates that axe blanks are broader than other types, whereas pick are the narrowest. High length/breadth index ratio for handaxe indicates that they are longer than others, while picks are shorter. When refinement is taken into account, handaxe have a high mean value (1.79) with high coefficient of variation value (CV=0.20). High mean value and high coefficient of variation value indicates that the handaxes are the thinnest with more variation in them, while picks are the thickest.

All these indicate that picks are narrower, shorter and thicker large cutting tool types, while handaxes are longer and thinner, but broader than picks.

A bivariate correlation test was conducted to see whether these indexes have any correlations between each others. But this bivariate correlation test revealed no correlation between the index values.

4.20. Differentiating large cutting tools

A discriminant function analysis was conducted using all general and additional measurements for shape/morphological measures of large cutting tools from Benkaneri, in order to differentiate within the large cutting tool types. Figure 4.20.1., clearly shows that there are three centroid groups within the large cutting tools from Benkaneri. The first group consists of handaxe, the second group with axe blank and the third group consisted of cleaver.

Table 4.20.1. Obtaining eigenvalues with the help of two functions for differentiating large cutting tool types from Benkaneri.

Eigenvalues				
Function	**Eigenvalue**	**% of Variance**	**Cumulative %**	**Canonical Correlation**
1	51.578	96.008	96.008	0.990
2	2.1446	3.9920	100.0000	0.8258

Table 4.20.1 ,4.20.2, & 4.20.3 and Figure 4.20.1., provides the information on two centroidal groups that was obtained by comparing maximum dimension, maximum width, thickness, tip width, mid width, base width, tip thickness, mid thickness and base thickness of large cutting tool types. In this discriminant analysis two eigenvalues were obtained, in order to perform 2 canonical discriminant functions (Table 4.20.1). With the help of these two eigenvalues, two functions were obtained for group centroids (Table 4.20.2).

Table 4.20.2. Two functions of large cutting tool types for obtaining group centroidal values.

Functions at Group Centroids		
Flaked piece	**Function**	
	1	**2**
Handaxe	3.350	1.336
Cleaver	-12.001	0.128
Axe Blank	2.650	-1.400

Table- clearly shows that handaxe and axe blank fall in one group and the cleaver falls in the second group (Figure 4.20.1). The first group had positive centroidal value and second group had negative centroidal value.

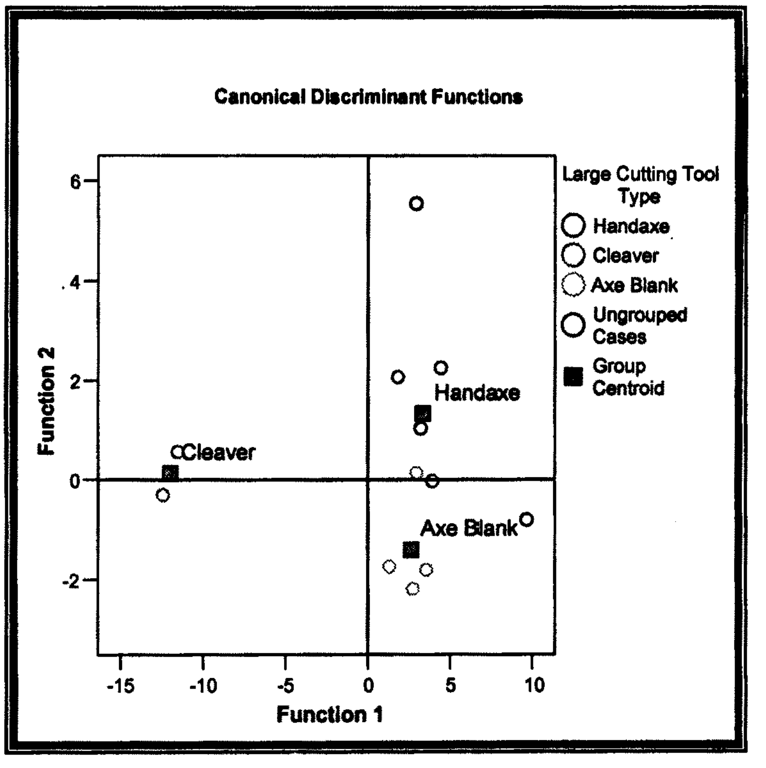

Figure 4.20.1. A scatter plot of discriminant functions 1 and 2 for large cutting tool types from Benkaneri.

The positive centroidal value comprised of handaxe and axe blank, and whereas the negative centroidal value comprised of cleaver. Fisher's linear discriminant function also explains and strengthens the fact that cleavers are different from handaxe and axe blank (Table 4.20.3).

Table 4.20.3. Is the Classification Function Coefficients of large cutting tools with its general and addition measurements by Fisher's linear discriminant functions.

Classification Function Coefficients			
Additional Measurements	**Large Cutting Tool Type**		
	Handaxe	**Cleaver**	**Axe Blank**
B 1	-16.83	-7.66	-16.48
Mid Width	32.97	18.74	32.94
B3	19.24	12.91	18.83
Th1	-69.90	-44.10	-67.91
Mid Thick	10.47	7.63	10.22
Th3	16.77	9.26	16.34
Maximum Width	-22.17	-13.83	-22.47
(Constant)	-506.37	-266.21	-477.36

In support for the above figure (Figure 4.20.1), Fisher's linear discriminant function is the classification Function of Coefficients for large cutting tools with its general and addition measurements. Table 4.20.3., clearly shows that tip width (B1), mid width (B2), base width (B3), tip thickness (T1), mid thickness (T2), base thickness (T3), maximum dimension, maximum width and thickness for handaxe and axe blank values are similar to each other than cleavers. Figure 4.20.2., indicates that the mean value for tip width of handaxe, axe blank and pick are almost same, but at the same time the mean value for cleaver are significantly different.

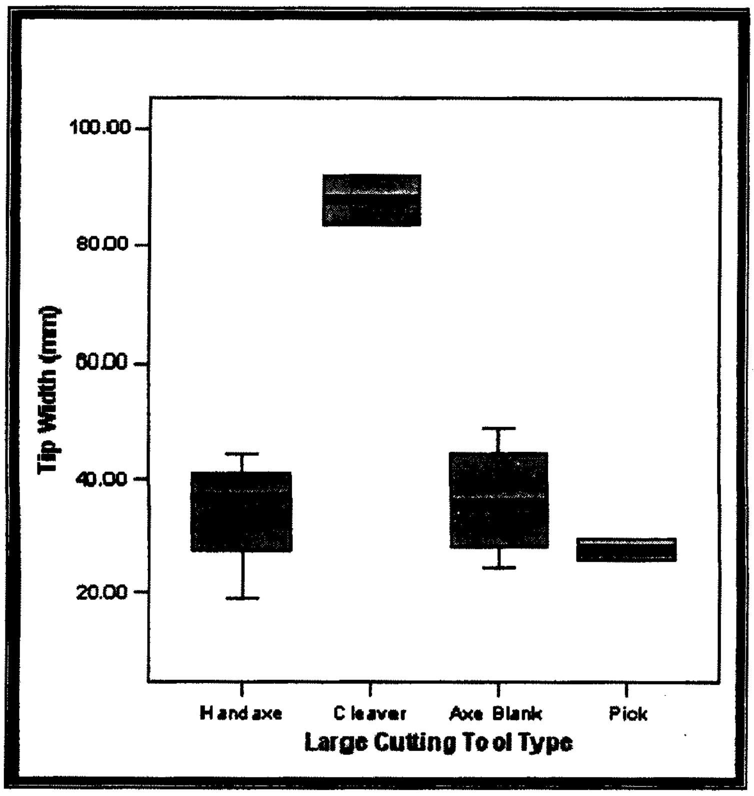

Figure4.20.2. Box plot of tip width for large cutting tool types from Benkaneri

4.21. Accessing variability within large cutting tool types

As said in the previous section where large cutting tools from Khyad were analyzed in order to explain the variability as observed in the assemblage, in the same way the large cutting tools from Benkaneri is analyzed. The variability in large cutting tool will be explained with the help of variability in raw material (types, size and shape) and stages of reduction.

Influence of raw material on the variability observed in the large cutting tool types

This section of analysis examines the frequency of large cutting tools manufactures on specific raw material types. The hypothesis being tested is that raw material physical differences are reflected in large cutting tools measurement and form-defining ratio. At Benkaneri, all large cutting were manufactured only on quartzarenites (quartzite) (Table 4.13.1). Due to the absence of any other raw material and absolute counts in quartzarenites (quartzite) type of raw material, no statistical analysis could be done. For this reason, raw material type could not explain the variability in morphology of large cutting tools.

Influence of initial form on the variability observed in the large cutting tool types

In order to test the effect of shape and size of raw material on the variability in morphology of large cutting tools, initial form and cortex type of large cutting tool types were compared with general and additional measurements.

Out of 19 large cutting tools, 14 were complete and 5 were broken, but all of them retained information of the initial form. Among 19 large cutting tools, 8 were handaxe, 5 were axe blank, 2 cleavers, 3 picks and 1 chopper. Majority of the large cutting tools have very little information on the initial form, it is testified by the fact that the indeterminate category of initial form was the highest and was followed by flake, cobbles and blocky initial form type (Figure4.21.1).

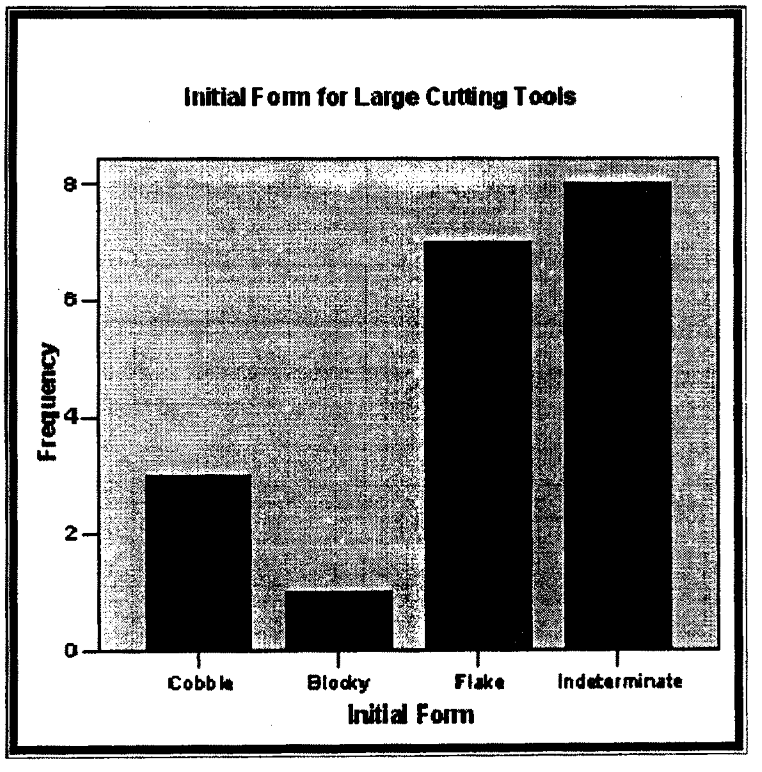

Figure4.21.1. Bar graph of initial form for large cutting tools from Benkaneri.

Table 4.21.1. Mean, standard deviation and coefficient of variation of general metrical measurements for large cutting tool types from Benkaneri site broken down by its initial form.

Type	Initial Form	Variable	N	Mean	Std. Deviation	CV
Handaxe	Flake	Maximum Dimension	3	107.42	3.96	0.04
		Maximum Width	3	71.19	8.79	0.12
		Thickness	3	37.20	5.48	0.15
		Weight	3	271.67	63.31	0.23
	Indeterminate	Maximum Dimension	5	125.22	73.98	0.59
		Maximum Width	5	77.72	28.00	0.36
		Thickness	5	44.97	9.77	0.22
		Weight	5	521.30	543.57	1.04
Axe Blank	Flake	Maximum Dimension	3	123.99	16.49	0.13
		Maximum Width	3	82.55	13.99	0.17
		Thickness	3	43.94	3.29	0.07
		Weight	3	435	172.99	0.40
	Cobble	Maximum Dimension	1	142.38	0	0
		Maximum Width	1	85.68	0	0
		Thickness	1	60.37	0	0
		Weight	1	573	0	0
	Indeterminate	Maximum Dimension	1	101.93	0	0
		Maximum Width	1	47.15	0	0
		Thickness	1	26.04	0	0
		Weight	1	160.6	0	0
Cleaver	Flake	Maximum Dimension	1	184.92	0	0
		Maximum Width	1	138.3	0	0
		Thickness	1	62.89	0	0
		Weight	1	1475	0	0
	Indeterminate	Maximum Dimension	1	134.64	0	0
		Maximum Width	1	88.36	0	0
		Thickness	1	47.12	0	0
		Weight	1	578	0	0
Pick	Cobble	Maximum Dimension	1	92.82	0	0
		Maximum Width	1	81.03	0	0
		Thickness	1	47.75	0	0
		Weight	1	268	0	0
	Blocky	Maximum Dimension	1	141.82	0	0
		Maximum Width	1	94.58	0	0
		Thickness	1	74.98	0	0
		Weight	1	907	0	0
	Indeterminate	Maximum Dimension	1	100.42	0	0
		Maximum Width	1	63.54	0	0
		Thickness	1	52.18	0	0
		Weight	1	277	0	0
Chopper	Cobble	Maximum Dimension	1	110.03	0	0
		Maximum Width	1	91.78	0	0
		Thickness	1	71.85	0	0
		Weight	1	770	0	0

Table 4.21.1., show that 3 handaxes were made from flakes and 5 of them had little information on the initial form, so they were assigned to indeterminate form type. Out of 5 axe blanks, 3 were made from flake, 1 from cobble and 1 from indeterminate. Cleavers were 2 in total and they were made from flake and indeterminate, while 3 picks were made from cobble, blocky and indeterminate. Choppers were the least in count (n=1) and

this chopper was made from cobble. Table 4.21.1., shows, handaxe which had little information on the initial forms and was grouped in the indeterminate category were the longest, widest, thickest and heaviest than the handaxes made from flakes. Axe blanks which were made from cobble were the longest, widest, thickest and heaviest than axe blanks made from flakes and indeterminate, whereas axe blank which had little information on the initial forms were the shortest, narrowest, thinnest and lightest from others. Cleavers made on flakes were longest, widest, thickest and heaviest than cleavers made on indeterminate. Picks made from blocky initial form were the longest, widest, thickest and heaviest than picks made from cobble and indeterminate, whereas picks made from cobble were the shortest, narrowest, thinnest and lightest than others. From this site, only 1 chopper was found and it was made from cobble. These inferences from Table 4.21.1., should be taken cautiously because most of the information on the initial form is least in count.

Table 4.21.2., shows comparison made between and within initial forms of large cutting tool types with index ratios. The initial forms of all large cutting tools were of from the same raw material i.e., quartzarenites (quartzite) (as mentioned in the previous section of this chapter). From Table 4.21.2., it is evident that, initial form of handaxes were from flakes as well as indeterminate. Handaxes which were made from indeterminate are broader (0.53), longer (2) and thicker (1.70); whereas, handaxes made from flakes are narrower (0.51), shorter (1.53) and thinner (1.94). Axe blanks which were made from cobbles are broader (0.75) and are thicker (1.42) than other initial forms. Axe blanks made from flakes are narrower (0.56), shorter (1.22) and are thinner (1.87), whereas, axe blanks made from indeterminate are longest (2.16) than other initial forms. Two cleavers that were collected from the site Benkaneri were made on flake and indeterminate. Cleaver made on flakes are narrower (0.85), shorter (1.34) and thinner (2.20), whereas, cleaver made on indeterminate are longer (1.52), broader (1.33) and thicker (1.88). The initial forms

for picks were cobble, blocky and indeterminate. Picks that were made from cobble are shorter (1.15), narrower (0.37) and thinner (1.70), whereas, picks made from indeterminate are longer (1.58), broader (0.50) and thicker (1.22).

Table 4.21.2 Mean, standard deviation and coefficient of variation of shape defining index ratio for large cutting tool types from Benkaneri site broken down by its initial form.

Types	Initial Form	Index Ratio	Mean	Std. Deviation	CV
Handaxe	Flake	Edge Shape (B1/B3)	0.51	0.13	0.25
		Elongation (L/B)	1.53	0.21	0.14
		Refinement (B/T)	1.94	0.41	0.21
	Indeterminate	Edge Shape (B1/B3)	0.53	0	0
		Elongation (L/B)	2	0	0
		Refinement (B/T)	1.70	0.34	0.20
Axe Blank	Flake	Edge Shape (B1/B3)	0.56	0.16	0.29
		Elongation (L/B)	1.22	0.31	0.26
		Refinement (B/T)	1.87	0.19	0.10
	Cobble	Edge Shape (B1/B3)	0.75	0	0
		Elongation (L/B)	1.66	0	0
		Refinement (B/T)	1.42	0	0
	Indeterminate	Edge Shape (B1/B3)	0.58	0	0
		Elongation (L/B)	2.16	0	0
		Refinement (B/T)	1.81	0	0
Cleaver	Flake	Edge Shape (B1/B3)	0.85	0	0
		Elongation (L/B)	1.34	0	0
		Refinement (B/T)	2.20	0	0
	Indeterminate	Edge Shape (B1/B3)	1.33	0	0
		Elongation (L/B)	1.52	0	0
		Refinement (B/T)	1.88	0	0
Pick	Cobble	Edge Shape (B1/B3)	0.37	0	0
		Elongation (L/B)	1.15	0	0
		Refinement (B/T)	1.70	0	0
	Blocky	Edge Shape (B1/B3)		0	0
		Elongation (L/B)	1.50	0	0
		Refinement (B/T)	1.26	0	0
	Indeterminate	Edge Shape (B1/B3)	0.50	0	0
		Elongation (L/B)	1.58	0	0
		Refinement (B/T)	1.22	0	0

Influence of cortex type on the variability observed in the large cutting tool types

Cortex type was also recorded in order to test the effect of shape and size of raw material on the variability in morphology of large cutting tools and preference of clast type by the hominins at this site.

Majority of large cutting tool types which had the information on the cortex was of angular and the rest of cortex types were in least count (n=1). Out of 19 large cutting tools only 7 had the information on the cortex type.

Table 4.21.3.,and 4.21.4., explains the relation between and within the cortex types for large cutting tool types with its general linear measurements and index ratios. All handaxes and pick were made on angular clast type. Axe blanks were made on angular as well as sub-angular clast types. Axe blanks made from sub-angular were longer (142.38 mm) with high elongation index (1.66), wider/broader (85.68 mm) with high edge shape ratio (0.75), thicker (60.37 mm) with low refinement value (1.42) and was heavier (573 gms), whereas the angular types are much smaller (116.3 mm) with low elongation ratio (1.22), narrower (74.48 mm) with low edge shape ratio (0.56), thinner (42.17 mm) with high refinement ratio (1.77) and lighter (337.50 gms). Therefore, axe blanks made from sub-angular clast are bigger, thicker and heavier in size and shape than the axe banks made from angular clast type.

Table 4.21.3. Mean, standard deviation and coefficient of variation of general metrical measurements for large cutting tool types from Benkaneri site broken down by its cortex type.

Type	Cortex Type	Variable	Mean	Std. Deviation	CV
Handaxe	Angular	Maximum Dimension	108.80	0.00	0.00
		Maximum Width	61.41	0.00	0.00
		Thickness	36.01	0.00	0.00
		Weight	215.00	0.00	0.00
Axe Blank	Angular	Maximum Dimension	116.3	13.746156	0.12
		Maximum Width	74.48	0.8697413	0.01
		Thickness	42.17	1.62	0.04
		Weight	337.50	53.03	0.16
	Sub-Angular	Maximum Dimension	142.38	0.00	0.00
		Maximum Width	85.68	0.00	0.00
		Thickness	60.37	0.00	0.00
		Weight	573.00	0.00	0.00
Pick	Angular	Maximum Dimension	117.32	34.648232	0.30
		Maximum Width	87.81	9.5812969	0.11
		Thickness	61.37	19.254518	0.31
		Weight	587.50	451.84123	0.77
Chopper	Sub-Rounded	Maximum Dimension	110.03	0.00	0.00
		Maximum Width	91.78	0.00	0.00
		Thickness	71.85	0.00	0.00
		Weight	770	0.00	0.00

Table 4.21.4. Mean, standard deviation and coefficient of variation of shape defining index ratio for large cutting tool types from Benkaneri site broken down by its cortex type.

Types	Varibles	Index Ratio	Mean	Std. Deviation	CV
Handaxe	Angular	Edge Shape (B1/B3)	0.37	0.00	0.00
		Elongation (L/B)	1.77	0.00	0.00
		Refinement (B/T)	1.71	0.00	0.00
Axe Blank	Angular	Edge Shape (B1/B3)	0.56	0.16	0.29
		Elongation (L/B)	1.22	0.31	0.26
		Refinement (B/T)	1.77	0.09	0.05
	Sub-Angular	Edge Shape (B1/B3)	0.75	0.00	0.00
		Elongation (L/B)	1.66	0.00	0.00
		Refinement (B/T)	1.42	0.00	0.00
Pick	Angular	Edge Shape (B1/B3)	0.37	0.00	0.00
		Elongation (L/B)	1.32	0.25	0.19
		Refinement (B/T)	1.48	0.31	0.21

Influence of reduction sequence on the variability observed in the large cutting tool types

As suggested by McPherron, the reduction model primarily focuses primarily on the changes in shape that occur when the tip is reworked. Thus tip length will be primary measure of reduction intensity (McPherron 1999). This will be used to explain the variability seen in the large cutting types from Benkaneri. When large cutting tool's elongation, edge shape and refinement ratios were compared by using bivariate correlation test and other correlation test with tip length, it did not give any significant results. Scatter plot also did not give any meaning full result it might be due the fact that large cutting tools from Benkaneri were very low in count. In order to explain the variability between and within large cutting tools and for explaining the reduction stages at Benkaneri site, total flake scar count, total number of non-feather termination and index of invasiveness were compared with elongation, edge shape and refinement ratio of large cutting tools. For this reason scatter plot was plotted to give meaningful results.

Total flake scar count

As stone knapping is a reductive or subtractive 'multi-staged' reductive process, one in which the stone undergoes sequential stages of reduction as core mass is modified by the knapper. When the reductions advance, the count of flake removed increases and this could be notice on the flaked piece. Figure 4.21.2., reveals that the mean, inter-quartile range and its spread are high for total scar count in handaxe than any other large cutting tool types.

Figure 4.21.5 to 4.21.7., show that, as the reduction increases total scar count increases. Figure – is a comparison of elongation ratio with total scar cont. From this figure it is clear that as the elongation index increase the total scar count also increases. Shorter large cutting tools have few total flake scar count, whereas, longer large cutting tools have more total scar count. At the same time when total scar count is compared with edge shape ratio, not much difference could be noticed in the in increase or decrease in the total flake scar count (Figure 4.21.6). When refinement is compared with total scar count, it revealed that thicker large cutting tools have less total scar count, whereas thinner large cutting tools have more total scar count (Figure 4.21.7).

Index of invasiveness

Index of invasiveness is also a measure to measure the reduction process, as the reduction advances the index of invasiveness also increases. By comparing index of invasiveness with elongation, edge shape and refinement ratio, the variability in morphology within large cutting tools cloud be explained. Figure 4.21.3., reveals that the mean, inter-quartile range and its spread is high in handaxe, indicating variation in handaxe's index of invasive value, while pick has the highest mean value in index of invasiveness than any other tool type.

Figure 4.21.8 to 4.21.10., show that, as the reduction increases index of invasiveness increases. Figure 4.21.8., is a comparison of elongation ratio with index of invasiveness. From this scatter plot it is clear that as the elongation index increase the index of invasiveness also increases. Shorter large cutting tools have low index of invasiveness, whereas, longer large cutting tools have high index of invasiveness. At the same time when index of invasiveness is compared with edge shape ratio, narrower large cutting tools have low index of invasiveness value, whereas, broader large cutting tools have high index of invasiveness (Figure 4.21.9). When refinement is compared with index of invasiveness, it revealed that thicker large cutting tools have high value for index of invasiveness, whereas thinner large cutting tools have low index of invasiveness value (Figure 4.21.10).

Non-feather termination.

Total number of non-feather termination is also a measure to measure the reduction process, as the reduction advances the non-feather termination count also increases. By comparing total count of non-feather termination with elongation, edge shape and refinement ratio, the variability in morphology within large cutting tools can also be explained. Figure 4.21.4., reveals that the mean, inter-quartile range and its spread are high for non-feather termination in handaxe than any other large cutting tool types.

Figure 4.21.11 to 4.21.13 show that, as the reduction increases non-feather termination count also increases. Figure 4.21.11., is a comparison of elongation ratio with total count of non-feather termination. From this scatter plot it is clear that as the elongation index increase the total count of non-feather termination also increases. Shorter large cutting tools have low count of non-feather termination,

whereas, longer large cutting tools have high count of non-feather termination. When total count of non-feather termination is compared with edge shape ratio, not much difference could be noticed in the in increase or decrease in the total count of non-feather termination (Figure 4.21.12). When refinement is compared with total count of non-feather termination, it revealed that thicker large cutting tools show increase in the count of non-feather termination, whereas, thinner large cutting tools show less count in non-feather termination (Figure 4.21.13).

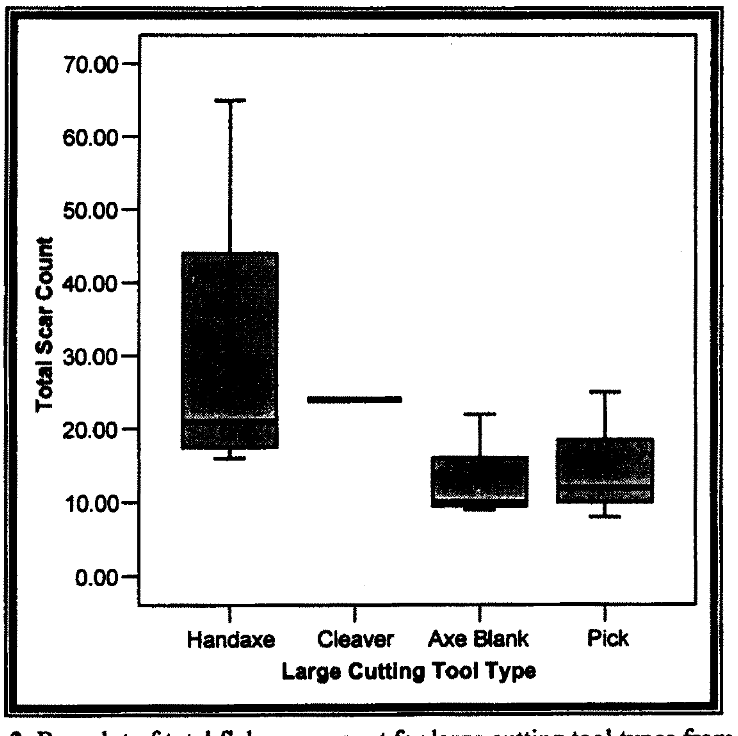

Figure 4.21.2. Box plot of total flake scar count for large cutting tool types from Benkaneri.

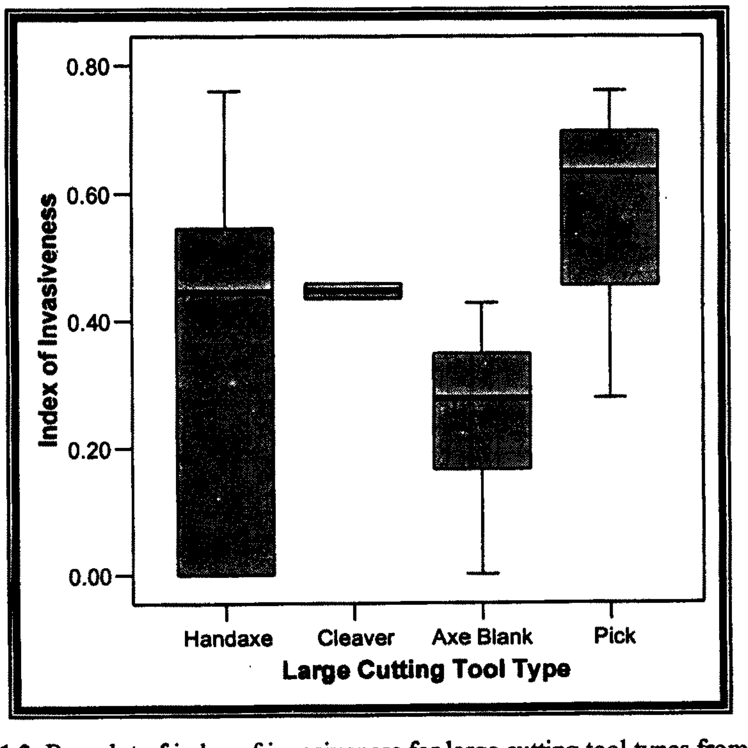

Figure 4.21.3. Box plot of index of invasiveness for large cutting tool types from Benkaneri.

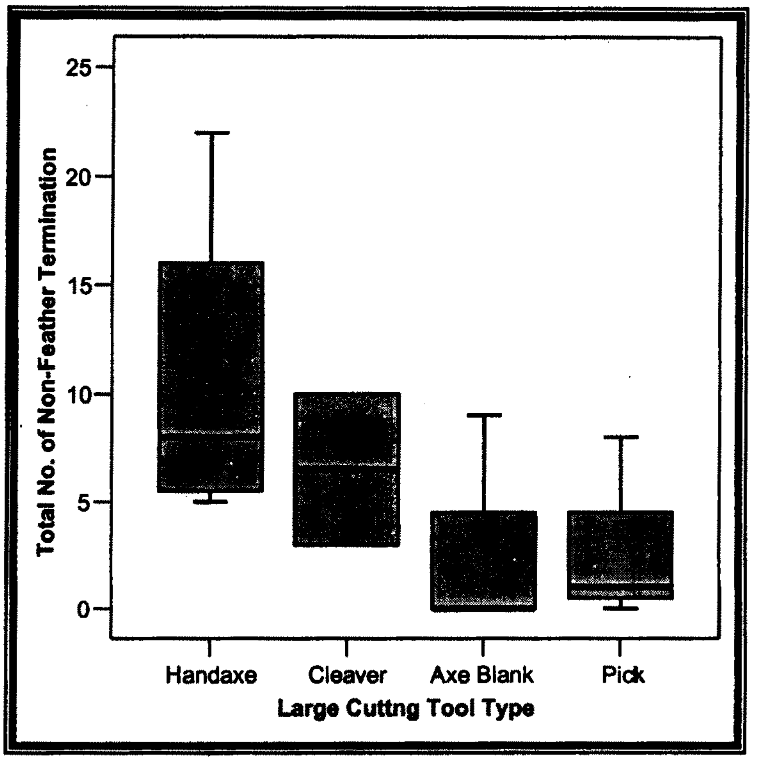

Figure 4.21.4. Box plot of total non-feather termination for large cutting tool types from Benkaneri.

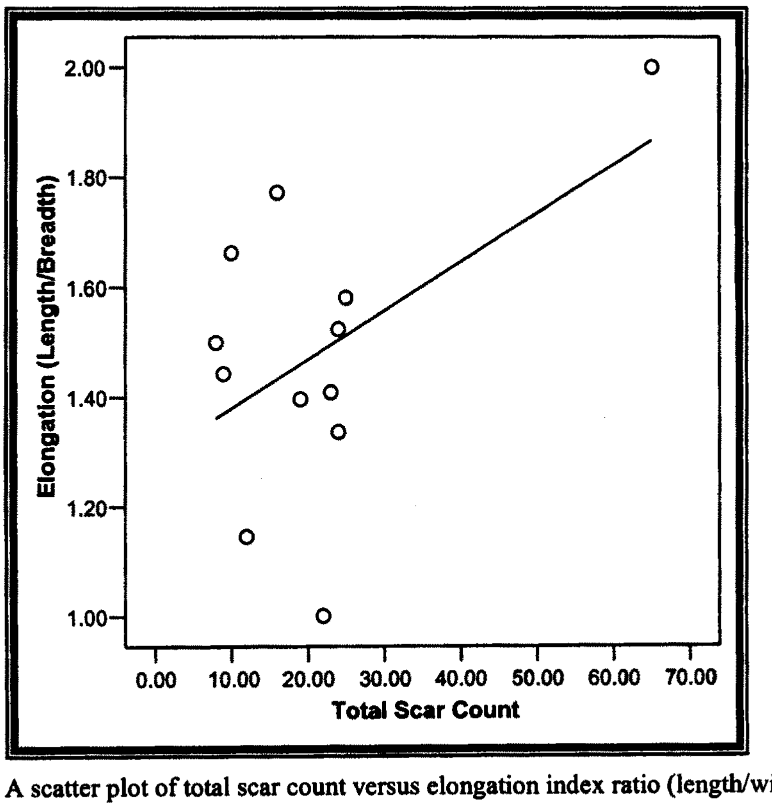

Figure 4.21.5. A scatter plot of total scar count versus elongation index ratio (length/width) for large cutting tool types from Benkaneri.

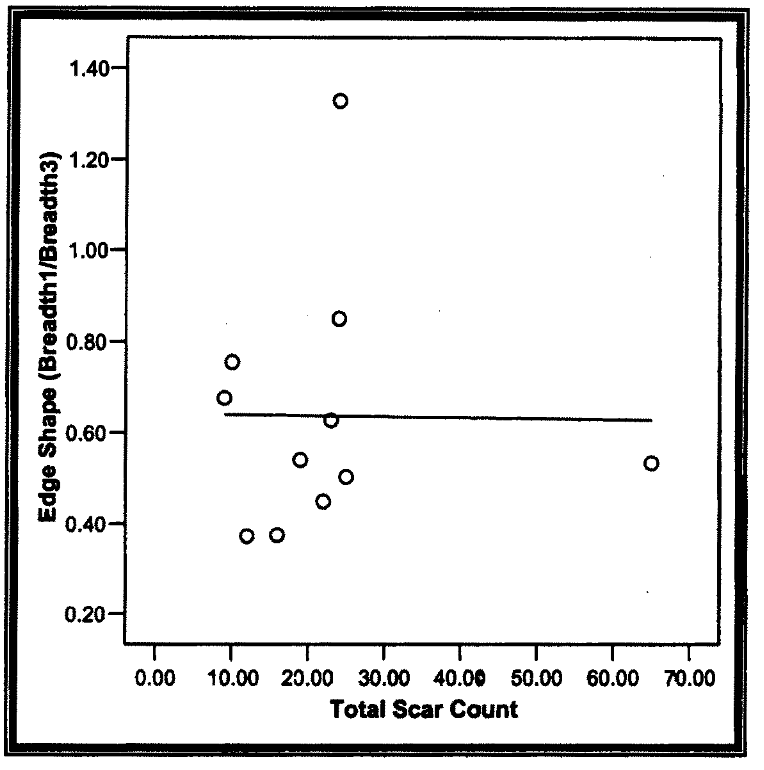

Figure 4.21.6. A scatter plot of total flake scar count versus edge shape index ratio (breadth1/breadth3) for large cutting tool types from Benkaneri.

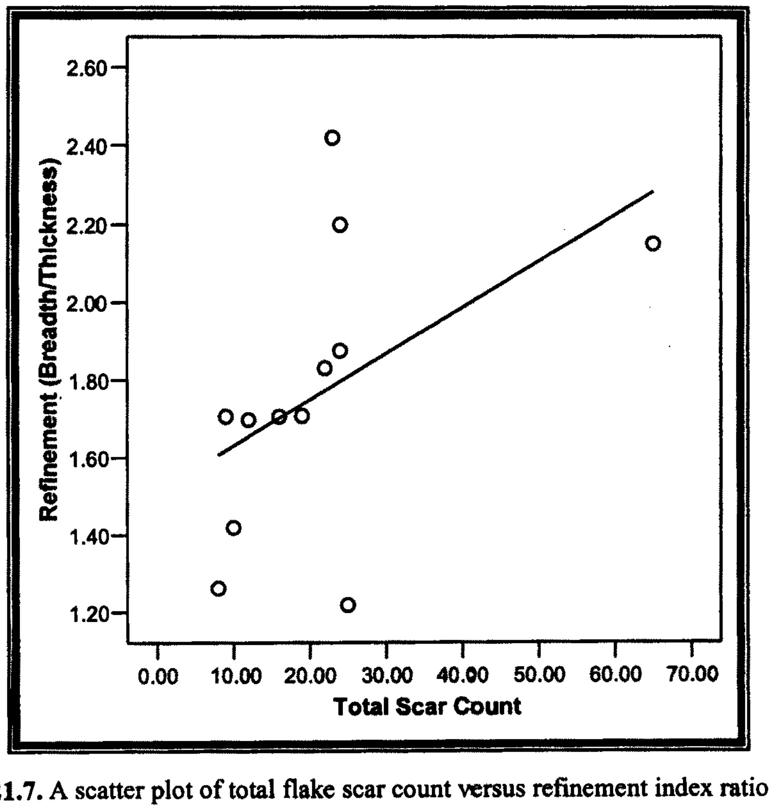

Figure 4.21.7. A scatter plot of total flake scar count versus refinement index ratio (width/thickness) for large cutting tool types from Benkaneri.

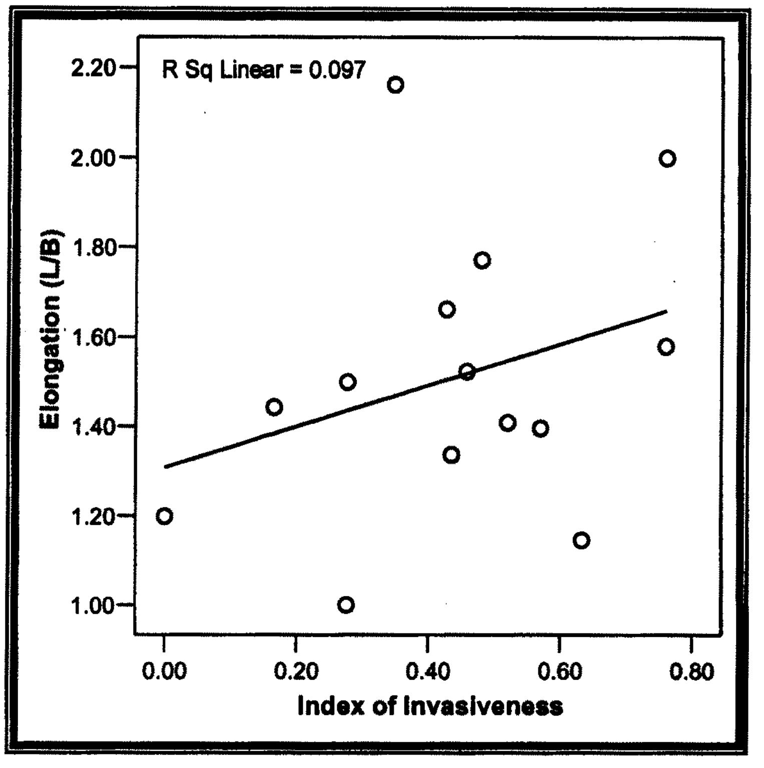

Figure 4.21.8. A scatter plot of index of invasiveness versus elongation index ratio (length/width) for large cutting tool types from Benkaneri.

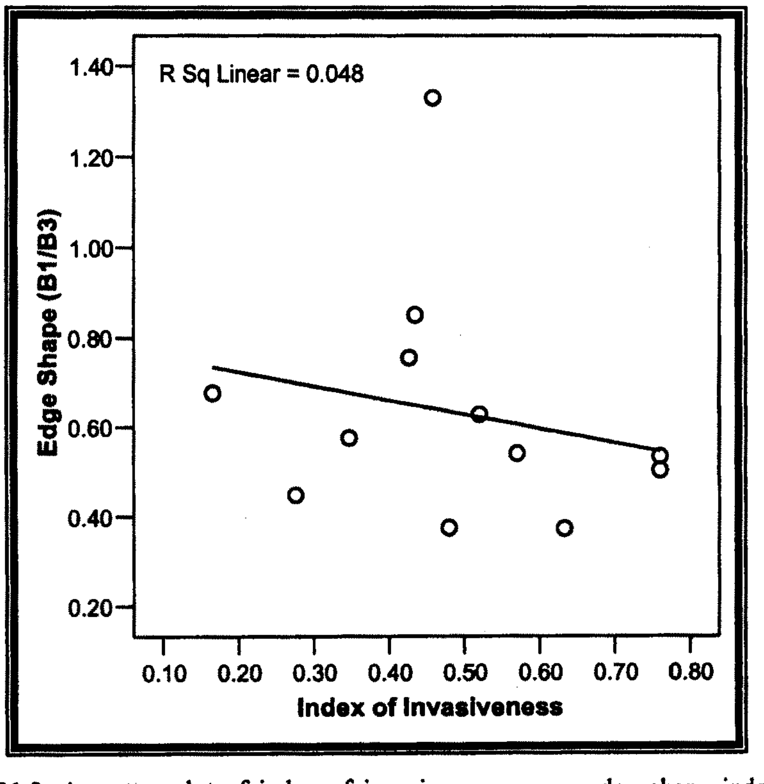

Figure 4.21.9. A scatter plot of index of invasiveness versus edge shape index ratio (breadthl/ breadth3) for large cutting tool types from Benkaneri.

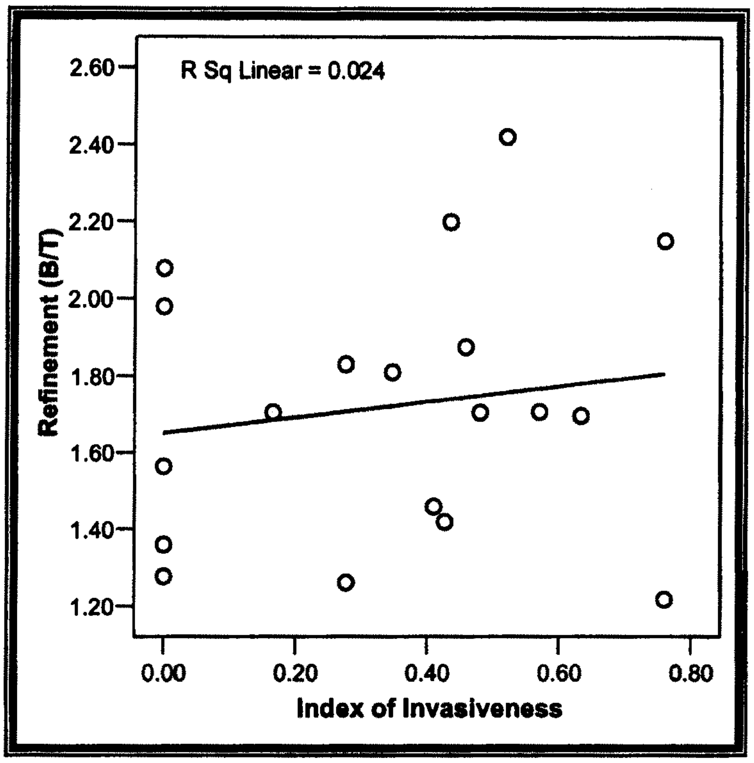

Figure 4.21.10. A scatter plot of index of invasiveness versus refinement index ratio (width/thickness) for large cutting tool types from Benkaneri.

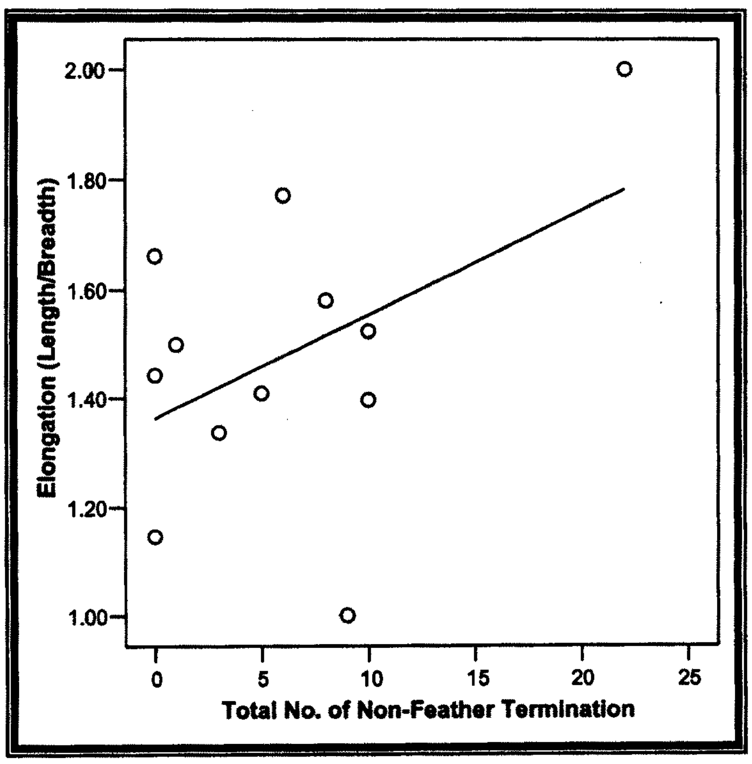

Figure 4.21.11. A scatter plot of total number of non-feather termination versus elongation index ratio (length/width) for large cutting tool types from Benkaneri.

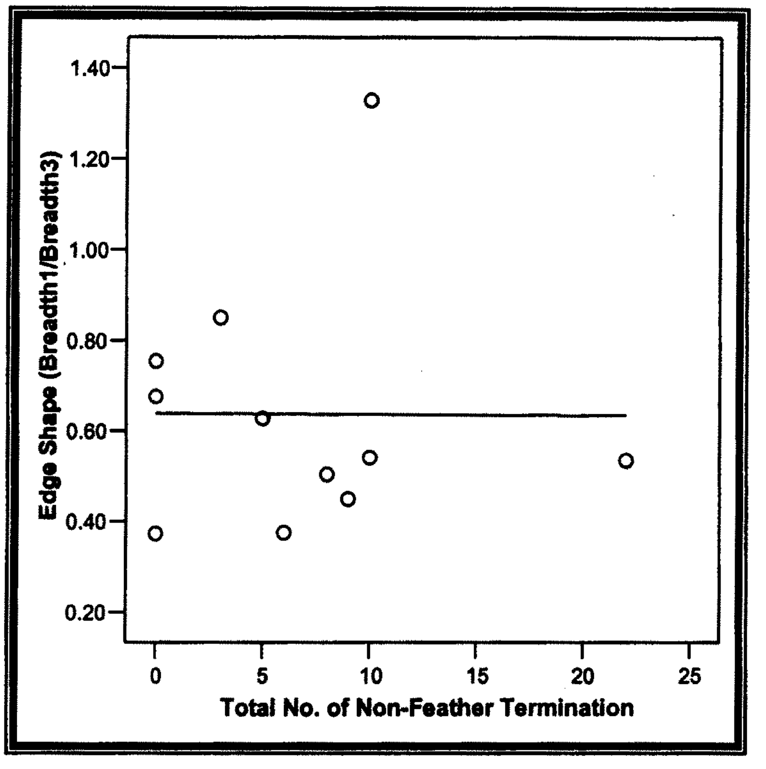

Figure 4.21.12. A scatter plot of total number of non-feather termination versus edge shape index ratio (breadth1/ breadth3) for large cutting tool types from Benkaneri.

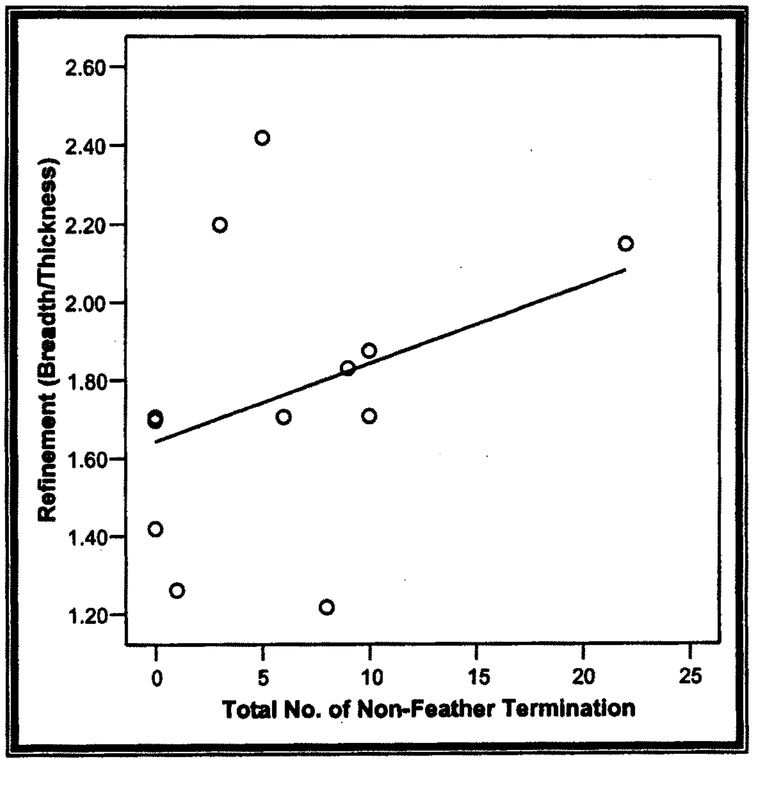

Figure 4.21.13. A scatter plot of total number of non-feather termination versus refinement index ratio (width/thickness) for large cutting tool types from Benkaneri.

In order to examine the reduction sequence of the large cutting tools as well as explain the morphological changes, a hypothesis was put forward.

- axe blanks were the initial form for handaxes
- cleaver blank were the initial form for cleavers

Due to low in count in cleavers and the absence of cleaver blanks, this type was excluded from this analysis.

Comparison between axe blank and handaxe.

In order to explain the reduction and variability present in handaxe will be explained with the help of comparing metrical and non-metrical attributes which define the size and shape of large cutting tools. These measurements are compared between axe blanks and handaxe in order to explain the reduction and variability present.

One-Way ANOVA correlation test for these attributes of handaxe and axe blank are not at all significant. In order to explain, in what way these attributes are not significant, tabulation, correlation tests and stem and leaf plots was used which explains the mean value and its interquartile range with its extreme values in a visual way.

Comparison between common metrical attributes.

Common metrical attributes like maximum dimension (length), maximum width and thickness are recorded in order to define the morphology of the tools. Table 4.21.5., shows, the mean value of maximum dimension, maximum width and thickness for axe blank is higher than handaxe. The coefficient of variation values is higher in handaxe for maximum dimension and maximum width, whereas the coefficient of variation values are higher in thickness for axe blank. Higher variation in handaxe's maximum dimension and maximum width, and less variation in axe blank's maximum dimension and maximum width, indicates that axe blank looked similar to each other in maximum dimension and maximum width, whereas, handaxes exhibits much variation within them. As reduction is a subtractive 'multi-staged' reductive process involving removal of flakes from the nuclei, this resulted in reduction of the initial form into formed objects and overall changes in morphology. This same trend is noticed, when axe blank is compared with the handaxe, therefore, the axe blanks were the initial form for handaxe and from the

axe blank only the handaxes were made resulting in variation in handaxe and less variation in initial form (axe blank).

Table 4.21.5. Mean standard deviation and coefficient of variation of general metrical measurement for axe blanks and handaxe from Benkaneri.

Type	Variable	Mean	Std. Deviation	CV
Axe Blank	Maximum Dimension	123.26	18.48	0.15
	Maximum Width	76.1	19.01	0.25
	Thickness	43.65	12.36	0.28
Handaxe	Maximum Dimension	118.55	56.72	0.48
	Maximum Width	75.27	21.94	0.29
	Thickness	42.06	8.91	0.21

Comparison between additional metrical attributes for defining shape and size of large cutting tools.

Table 4.21.6., shows relationship between axe blank and handaxe with the help of both mean values as well as coefficient values of tip width (B1), mid width (B2), base width (B3), tip thickness (T1), mid thickness (T2), base width (T3), base length and tip length. From the above table it is observed that, the tip width (36.18 mm), tip thickness (59.08 mm), base thickness (36.59 mm) and base length (53.17 mm) of axe blanks have higher mean value, at the same time tip width (34.23 mm), tip thickness (16.09 mm), base thickness (32.84 mm) and base length (52.35 mm) are lower in mean value. Higher mean value for axe blank and lower mean value for handaxe indicate that as reduction proceed the tip width, tip thickness, base thickness and base length decreases, same kind of relation can be noticed when axe blank's are compared with handaxe, where handaxe's tip width, tip thickness, base thickness and base length decreases and there is increase in tip length. The values for coefficient of variation is higher (CV=0.34) in handaxe, indicating greater variation among handaxe than axe blanks. All this indicate that handaxe are made from axe blank.

Table 4.21.6. Mean standard deviation and coefficient of variation of additional metrical measurement for axe blanks and handaxe from Benkaneri.

Type	Variable	Mean	Std. Deviation	CV
Axe Blank	Tip Width (B1)	36.18	10.54	0.29
	Mid Width (B2)	66.95	15.62	0.23
	Base Width (B3)	59.08	11.78	0.2
	Tip Thickness (Th1)	59.08	11.78	0.2
	Mid Thick (Th2)	36.91	10.36	0.28
	Base Thickness	36.59	8.44	0.23
	Base Length	53.17	8.6	0.16
	Tip Length	54.85	27.07	0.49
	Total	50.35	13.02	0.26
Handaxe	Tip Width (B1)	34.23	10.74	0.31
	Mid Width (B2)	71.58	23.6	0.33
	Base Width (B3)	65.06	13.42	0.21
	Tip Thickness (Th1)	16.09	6.86	0.43
	Mid Thick (Th2)	38.64	12.29	0.32
	Base Thickness	32.84	5.73	0.17
	Base Length	52.35	20.4	0.39
	Tip Length	88.83	47.87	0.54
	Total	49.95	17.61	0.34

Table 4.21.7., shows the relationship between the index ratio for axe blank and handaxe. This table shows that axe blank are broader, less elongated and thicker, whereas handaxe are narrower, more elongated and thinner. As reduction is a deductive process, the formed type tends to become narrower and thinner. This same aspect can be seen when axe blanks and handaxes are compared.

Table 4.21.7. Mean standard deviation and coefficient of variation of shape defining index ratio for axe blanks and handaxe from Benkaneri.

Types	Indices Defining Ratio	Mean	Std. Deviation	CV
Axe Blank	Edge Shape (B1/B3)	0.61	0.13	0.21
	Elongation (L/B)	1.57	0.48	0.31
	Refinement (B/T)	1.77	0.24	0.14
Handaxe	Edge Shape (B1/B3)	0.52	0.11	0.21
	Elongation (L/B)	1.64	0.29	0.18
	Refinement (B/T)	1.79	0.36	0.2

Table 4.12.8., indicates that the mean value of index of invasiveness, total scar count and total number of non-feather termination for handaxe are higher than axe blanks, indicating reduction from axe blank to handaxe.

Table 4.21.8. Mean standard deviation and coefficient of variation of general metrical measurement for axe blanks and handaxe from Benkaneri.

Type	Variable	Mean	Std. Deviation	CV
Axe Blank	Index of Invasiveness	0.24	0.17	0.68
	Total Scar Count	13.67	7.23	0.53
	Total No. of Non-Feather Termination	3	5.20	1.73
Handaxe	Index of Invasiveness	0.34	0.30	0.88
	Total Scar Count	30.75	23.01	0.75
	Total No. of Non-Feather Termination	10.75	7.80	0.73

4.22. Core types at Benkaneri

This section will qualitatively and quantitatively explore core types by analyzing its size and shape. Common metrical and non-metrical measurements are analyzed within and between the core types.

Two types of typology were assigned to cores that were collected from Benkaneri are as follows-

- The first typology that was assigned to cores were given on the basis of method and direction of flakes removal from core (i.e., multi-platform and bidirectional) and whereas,
- the second type was assigned on the basis of, types of blanks (blade and flake) removed.

From a total of 125 artifacts collected from Benkaneri, 14 were cores, among these 14 cores, 12 were multi-platform core, 1 was bidirectional and remaining 1 was multi-platform bola core.

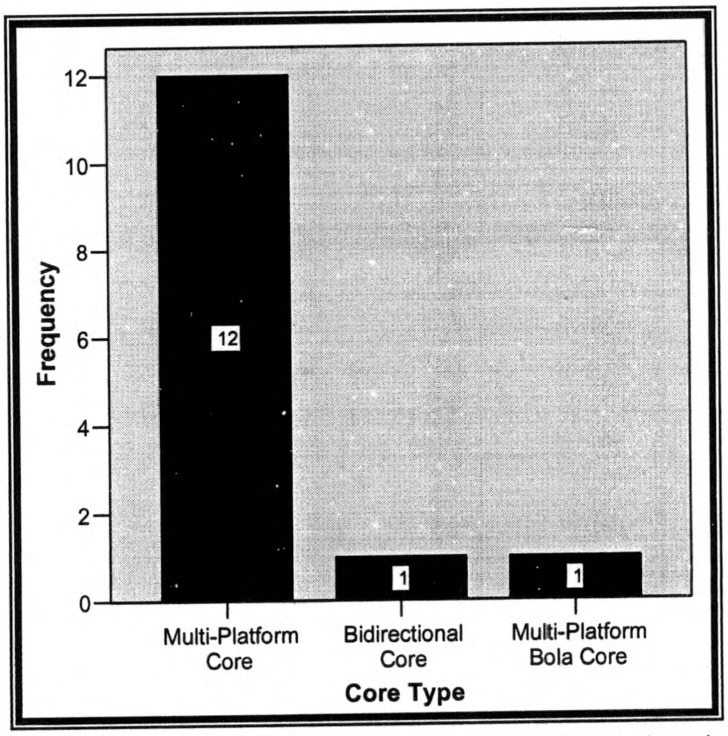

Figure 4.22.1. Bar graph for number of cores found from Benkaneri.

The second types of core, which was assigned, are blade, flake and blade & flake core, which were recorded in order to ascertain the targeted flakes for which the hominins at this site were reducing the natural clast.

From a total of 125 artifacts collected from Benkaneri, 14 were cores, among these 14 cores, 12 of them are flake core and 2 flake & blade core (Figure 4.22.2).

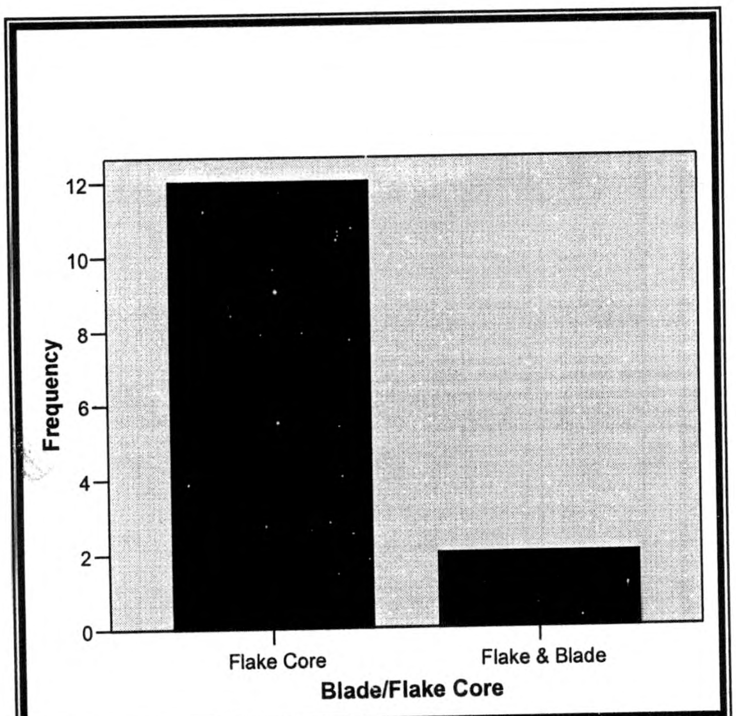

Figure 4.22.2. Bar graph for number of cores found from Benkaneri.

4.23. Non-metrical attributes recorded for core types

Common non-metrical attributes were recorded for cores (non-metrical are explained in the previous section as well as in the methodology section of this thesis). Simple bar, box plots and simple tables were used in order to explain these non-metrical attributes.

Raw material and grain size.

Majority of cores which were collected from this site were made from quartzarenites (quartzite) (12), 1 on chert and 1 on chert breccia. Out of these 12 quartzarenites (quartzite), 10 are multi-platform core, 1 is multi-platform bola core and 1 is bidirectional core. This majority for quartzarenites (quartzite) raw material type and low count for chert (n=1) and chert breccia (n=1) made it impossible to explore the effect of raw material on assemblage variability. As described in the beginning of this chapter quartzarenites (quartzite) have 1/16 to 2 mm, chert having <1/16 mm and chert breccia having >2 mm grain size; quartzarenites (quartzite) having 1/16 to 2 mm (Table 4.23.2)were the most oftenly procured raw material for reduction for removing flakes from the core. Chert and chert breccia were used in lesser amount, because these two types were non-local raw material.

Table 4.23.1., provides tabulation of lithic assemblage composition by core types and raw material types. Proportions are in parentheses by column, except for raw material type proportions, which are by row. Based on the results summarized in the Table---, majority of flake cores were made on quartzarenites (quartzite) (10), chert (1) and chert breccia (1), whereas, all flake and blade cores were made from quartzarenites (quartzite).

Table 4.23.1. Core types broken down by raw material types from Benkaneri.

Raw Material	Core Type			Total
	Multi-Platform Core	**Bidirectional Core**	**Multi-Platform Bola Core**	
Quartzarenites (quartzite)	10 (83.3)	1 (100)	1 (100)	12 (85.7)
Chert	1 (8.3)	0 (0.0)	0 (0.0)	1 (7.2)
Chert Breccia	1 (8.3)	0 (0.0)	0 (0.0)	1 (7.2)
Total	**12**	**1**	**1**	**14**

Table 4.23.2. Core types broken down by grain size types from Benkaneri.

Raw Material	Flake /Core Blade		Total
	Flake Core	Flake & Blade	
Quartzarenites (quartzite)	10 (83.3)	2 (100)	12 (87.7)
Chert	1 (8.3)	0 (0.0)	1 (7.2)
Chert Breccia	1 (8.3)	0 (0.0)	1 (7.2)
Total	**12**	**2**	**14**

Table 4.23.3., shows the relationship between core types. Out of 12 flake cores, 11 (83.3%) were made from multi-platform and remaining1 was made from bidirectional core (as multi-platform bola core is also a multi-platform core, it has been clubbed in multi-platform core), whereas, flake and blade core which are 2 in counts are made from multi-platform.

Table 4.23.3. Core types broken down by flake/blade core types from Benkaneri.

Flake/Blade Core	Core Type			Total
	Multi-Platform Core	Bidirectional Core	Multi-Platform Bola Core	
Flake Core	10 (83.3)	1 (8.3)	1 (8.3)	12
Flake & Blade	2 (100)	0 (0.0)	0 (0.0)	2
Total	**12 (85.7)**	**1 (7.1)**	**1 (7.1)**	**14**

Cortex type.

From 14 cores, 12 (85.7%) had the information on the cortex type. Majority of core were made on angular (7) and was followed by indeterminate (3), sub-angular (1) and sub-rounded (1).

Table 4.23.4. Cortex types for cores from Benkaneri.

Cortex Type	Frequency	Percent
Angular	7	58.3
Sub-Angular	1	8.3
Sub-Rounded	1	8.3
Indeterminate	3	25
Total	**12**	**100**

Out of these 12 cores which had information, are multi-platform core 10 (83.3%), bidirectional core 1 (8.33%) and multi-platform bola core 1 (8.33%).

Table 4.23.5. Core types broken down by cortex types from Benkaneri.

Cortex Type	Core Type			Total
	Multi-Platform Core	**Bidirectional Core**	**Multi-Platform Bola Core**	
Angular	7 (70%)	0 (0.00%)	0 (0.00%)	7
Sub-Angular	1 (10%)	0 (0.00%)	0 (0.00%)	1
Sub-Rounded	0 (0.00%)	0 (0.00%)	1 (100%)	1
Indeterminate	2 (20%)	1 (100%)	0 (0.00%)	3
Total	**10 (83.3%)**	**1 (8.33%)**	**1 (8.33%)**	**12**

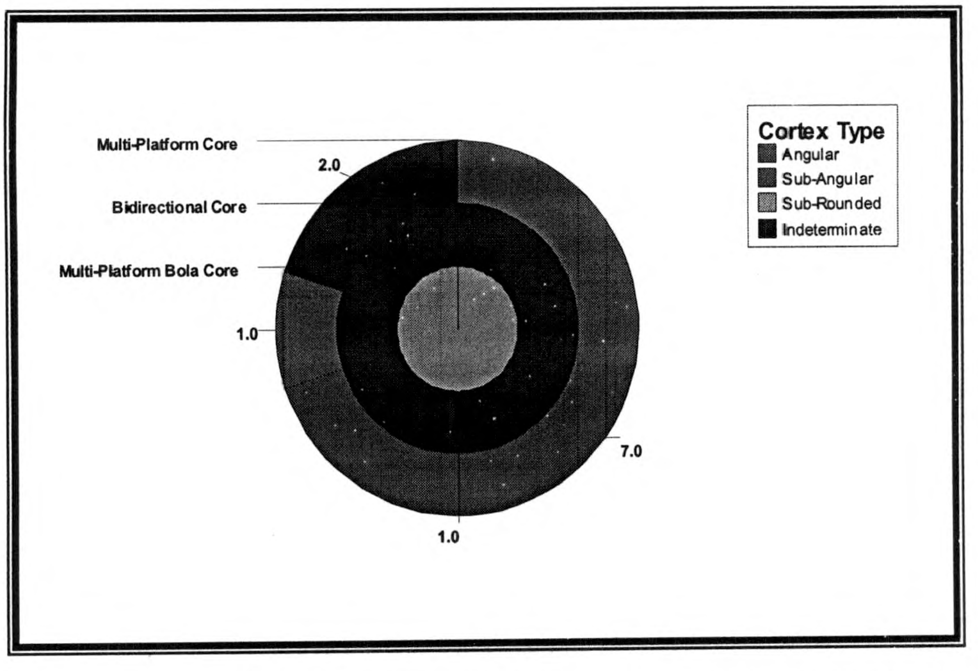

Figure 4.23.1. Pie graph for core types broken down by cortex types from Benkaneri.

From these 10 multi-platform core, 7 (70%) were made from angular clast type, 1 (10%) were made from sub-angular clast type and remaining 2 (20%) were made from indeterminate clast type (Figure 4.23.1) (Table 4.23.5) .

As mentioned above 12 core types had information on cortex type and out of these core types, 10 were flake cores and 2 were flake & blade. These 10 flake cores were made on 5 (50%) angular, 1 (10%) sub-angular, 1 (10%) sub-rounded and 3 (30%) had very little information on cortex type so it was grouped in indeterminate category, and remaining 2 (100%) flake & blade core were made on angular clasts (Table 4.23.6).

Table 4.23.6. Core types broken down by cortex types from Benkaneri.

Cortex Type	Flake /Core Blade		Total
	Flake Core	Flake & Blade	
Angular	5 (50)	2 (100)	7
Sub-Angular	1 (10)	0 (0.0)	1
Sub-Rounded	1 (10)	0 (0.0)	1
Indeterminate	3 (30)	0 (0.0)	3
Total	**10 (83.3)**	**2 (16.7)**	**12**

Platform Surface

Out of 14 cores, 11 had information on platform surface. From these 11 platforms, 1 had cortical surface, 1 had single conchoidal and 9 had multi conchoidal surface. As the multi-platform core is higher in number, it retains the highest amount of information on platform surface. Multi-platform core have 9 (100 %) multi conchoidal platforms, 1 (50%) single conchoidal and another 1 (100%) had cortical platform surface, whereas, bidirectional cores are 1 in count, they had single conchoidal (Table 4.23.7).

Table 4.23.7. Core types broken down by platform surface types from Benkaneri.

Platform Surface	Core Type		Total
	Multi-Platform Core	Bidirectional Core	
Single Conchoidal	1 (50)	1 (50)	2
Multiple Conchoidal	9 (100)	0 (0.0)	9
Cortical	1 (100)	0 (0.0)	1
Total	**11 (91.6)**	**1 (8.3)**	**12**

As mentioned above 12 core types had information on cortex type and out of these core types, 11 were flake cores and 1 were flake & blade. From these 11 flake cores, 9 (81.8%) had multi conchoidal platform, 1 (9.1%) had single conchoidal platform and 1 (9.1%) have cortical platform and at the same time flake and blade cores which are 1 in count has single conchoidal platform surface (Table4.23.8).

Table 4.23.8. Core types broken down by platform surface types from Benkaneri.

Platform Surface	Flake/Blade Core		Total
	Flake Core	Flake & Blade	
Single Conchoidal	1 (9.1)	1 (100)	2 (16.6)
Multiple Conchoidal	9 (81.8)	0 (0.0)	9 (75)
Cortical	1 (9.1)	0 (0.0)	1 (8.3)
Total	**11**	**1**	**12**

4.24. General metrical measurements for core type

Several important attributes were recorded in order to explain the variability within the core type common metrical attributes like maximum dimension, maximum width, thickness and weight were recorded in order to measure the shape and size of core.

From Table 4.24.1., it is easy to explain that the multi-platform cores are the longest (90.61 mm), widest (79.39 mm), thickest (53.53 mm) and heavier (396.60 gms) and this was followed by bidirectional core and multi-platform bola core. The multi-platform core which is bigger in size and shape, is made from quartzarenites (quartzite), having 1/16 to 2 mm grain size were longest, widest, thickest and heaviest.

Table 4.24.1. Mean, standard deviation and coefficient of variation for general metrical measurements of cores types from Benkaneri.

Core Type	Variable	Mean	Std. Deviation	CV
Multi-Platform Core	Maximum Dimension	90.61	20.64	0.23
	Maximum Width	79.39	15.70	0.20
	Thickness	53.53	9.70	0.18
	Weight	396.60	256.09	0.65
Bidirectional Core	Maximum Dimension	96.63	0	0
	Maximum Width	78.21	0	0
	Thickness	52.20	0	0
	Weight	320	0	0
Multi-Platform Bola Core	Maximum Dimension	59.88	0	0
	Maximum Width	54.36	0	0
	Thickness	46.45	0	0
	Weight	176.30	0	0

Table 4.24.2., shows that flake cores are the longest (90.93 mm), widest (79.44 mm), thickest (52.97 mm) and heavier (403.66 gms) and whereas, flake & blade core are shorter (76.35 mm), narrower (65.99 mm), thinner (52.63 mm) and lighter (205.80 mm) than flake core.

Table 4.24.2. Mean, standard deviation and coefficient of variation for general metrical measurements of cores types from Benkaneri.

Core Type	Variable	Mean	Std. Deviation	CV
Flake Core	Maximum Dimension	90.93	21.48	0.24
	Maximum Width	79.44	16.33	0.21
	Thickness	52.97	9.67	0.18
	Weight	403.66	251.20	0.62
Flake & Blade	Maximum Dimension	76.35	13.58	0.18
	Maximum Width	65.99	6.78	0.10
	Thickness	52.63	7.31	0.14
	Weight	205.80	90.79	0.44

4.25. Additional metrical measurements recorded for core type

From Table 4.25.1., it is clear that multi-platform core has the lowest value in all variables (i.e., scar>15mm, longest face, number of rotations, number of non feather termination, number of elongated parallel scars, last platform angle, number of platform quadrants and total flake scar count) except longest flake removed (53.92 mm) than the other two types namely bidirectional and multi-platform bola cores, because the scar>15mm (8), longest face (86.2 mm) and number of rotations (6) and longest flake removed (76.81 mm) of bidirectional are greater, when compared with multi-platform and multi-platform bola cores, and whereas, number of non feather termination (3), number of elongated parallel scars (4), last platform angle (105), number of platform quadrants (6) and total flake scar count (8) of multi-platform bola core are greater than the values of bidirectional core. This result should be cautiously taken because bidirectional and multi-directional bola core are in the least count (n=1). Therefore Table 4.25.1., indicate that maximum amount of reduction took place on multi-platform bola core, because as reduction increases, the total flake scar count, number of non feather termination and last platform angle also increases, whereas, scar count>15mm, longest face and longest flake removed decreases.

Table 4.25.1. Mean, standard deviation and coefficient of variation for adttional metrical measurements of cores types from Benkaneri.

Core Type	Variable	Mean	Std. Deviation	CV
Multi-Platform Core	Scars>15mm	5.75	2.67	0.46
	Longest Face	83.09	20.83	0.25
	Number of Rotations	4.17	1.47	0.35
	No. Non-Feather Termination	1.73	1.35	0.78
	No. Elongated Parallel Scars	2.75	0.96	0.35
	Last Platform Angle	85.08	8.10	0.10
	No. of Platform Quadrants	3.67	1.30	0.36
	Total Flake Scar Count	5.75	2.67	0.46
	Longest Flake Removed	53.92	11.48	0.21
Bidirectional Core	Scars>15mm	8	0	0
	Longest Face	86.2	0	0
	Number of Rotations	6	0	0
	No. Non-Feather Termination	1	0	0
	No. Elongated Parallel Scars	0	0	0
	Last Platform Angle	77	0	0
	No. of Platform Quadrants	3	0	0
	Total Flake Scar Count	6	0	0
	Longest Flake Removed	76.81	0	0
Multi-Platform Bola Core	Scars>15mm	6	0	0
	Longest Face	45.68	0	0
	Number of Rotations	4	0	0
	No. Non-Feather Termination	3	0	0
	No. Elongated Parallel Scars	4	0	0
	Last Platform Angle	105	0	0
	No. of Platform Quadrants	6	0	0
	Total Flake Scar Count	8	0	0
	Longest Flake Removed	42.09	0	0

From Table 4.25.2., it is clear that flake core have the highest mean value in scar>15mm, longest face, number of rotations, number of non feather termination, number of elongated parallel scars, last platform angle, number of platform quadrants, total flake scar count and longest flake removal than flake & blade core which has the lowest mean value. Whereas, coefficient value for number of rotation of flake core is lower (CV=0.31) than flake & blade core (CV=0.47). Therefore

Table 4.25.1., indicate that maximum amount of reduction took place on flake & blade core suggesting that it is in the last stage of reduction, it is because as reduction increases the size and shape of core decreases with all its aspects like scar>15mm, longest face, number of rotations, number of elongated parallel scars, number of platform quadrants, total flake scar count and longest flake removal. This same kind of feature is noticed on flake & blade core at Benkaneri. Flake & blade cores from Benkaneri are shorter, narrower, thinner and lighter (Table 4.25.2) with lowest mean value of scar>15mm, longest face, number of rotations, number of non feather termination, number of elongated parallel scars, last platform angle, number of platform quadrants, total flake scar count and longest flake removal (Table 4.25.2), indicative of last stage of reduction and at the same time coefficient of variation is also lower in flake & blade core for the above said variables, indicating less variation.

Table 4.25.1. Mean, standard deviation and coefficient of variation for additional metrical measurements of cores types from Benkaneri.

Core Type	Variable	Mean	Std. Deviation	CV
Flake Core	Scars>15mm	6.25	2.56	0.41
	Longest Face	83.30	22.36	0.27
	Number of Rotations	4.50	1.38	0.31
	No. Non-Feather Termination	1.82	1.25	0.69
	No. Elongated Parallel Scars	3.33	1.15	0.35
	Last Platform Angle	87.08	9.81	0.11
	No. of Platform Quadrants	4.00	1.35	0.34
	Total Flake Scar Count	6.25	2.56	0.41
	Longest Flake Removed	55.77	13.51	0.24
Flake & Blade	Scars>15mm	4.00	1.41	0.35
	Longest Face	64.67	1.57	0.02
	Number of Rotations	3.00	1.41	0.47
	No. Non-Feather Termination	1.50	2.12	1.41
	No. Elongated Parallel Scars	2.50	0.71	0.28
	Last Platform Angle	79.00	1.41	0.02
	No. of Platform Quadrants	2.50	0.71	0.28
	Total Flake Scar Count	4.00	1.41	0.35
	Longest Flake Removed	48.35	1.60	0.03

4.26. Accessing variability within core types

Influence of reduction stages on the variability observed in the core types

Cores are defined as intentionally knapped lithic artifacts from which useful flakes have been removed. A core is irreversibly reduced in mass when flakes have been removed from it. During this process the shape of core changes. Accordingly, knapping a stone can be viewed as a 'multi-staged' reductive process one, in which the stone undergoes sequential stages of reduction as core mass is modified by the knapper (Adam *et al.*, 2007). From this it can be speculated that, continuing reduction of cores will result in more flake scars and simultaneously the cortex will also decrease. Further removal of more flakes will result in decrease in size of core and resulting flakes might also be small. During this process of reduction the shape of core changes and the old platform gets damaged by the removal of flake. In order to create a fresh platform the core is rotated and as the rotation continuous the morphology of cores might get changed. In order to access the morphological changes over the sequence of core reductions, a number of variables are plotted against increasing core rotation. Another way to understand the core reduction and its effect on the morphology of core, a number of variables are plotted against the core size.

Number of variables plotted against increasing core rotation.

When number of variables was plotted against increasing core rotation, the total number of flake scar, number of platform perimeters on core increased with each rotation (Figure 4.26.1). Core with cortical platform has the least number of rotations and is followed by single conchoidal platform, whereas, multi conchoidal platform core has the highest number of rotation (Figure 4.26.1), indicative of stages of reduction. In the initial stage of reduction the core has cortical platform with minimum number of rotation and as the reduction proceeds, rotation increases with single conchoidal platform, further reduction results in multi conchoidal platform (prepared platform) with an increase in rotation from the previous ones (Figure 4.26.1). The count for non-feather termination (step and hinge) and external angle of the last platform increase as the rotation increases (Figure 4.26. 12), indicative of less reduced core have fewer number of non-feather termination with low external platform angle (Figure 4.26.2) and as the core is reduced considerably, the count of

non-feather termination increases with high external platform angle. When rotation increases number of platform quadrants also increases (Figure 4.26.5), indicating that as the reduction increase the platform perimeter was completely exhausted with high rotation in order to remove maximum number of flake from the core. One more interesting aspect was noticed, and that was, when, rotation increases, number of elongated parallel scar (Figure 4.26.7) and longest flake removed (Figure 4.26.6) from the core at first increases and then decreases as the rotation increases, this indicates that at initial stage of reduction elongated big flakes were removed and as the reduction proceeds the length of flake decreases. Whereas, cortex % diminishes gradually (Figure 4.26.3) with the decrease in maximum dimension (Figure 4.26.8), maximum width (Figure 4.26.10) and thickness (Figure 4.26.11) as the rotation increases. This indicates that as reduction advances, the maximum dimension, maximum width and thickness decreases with the decrease in cortex % of the core.

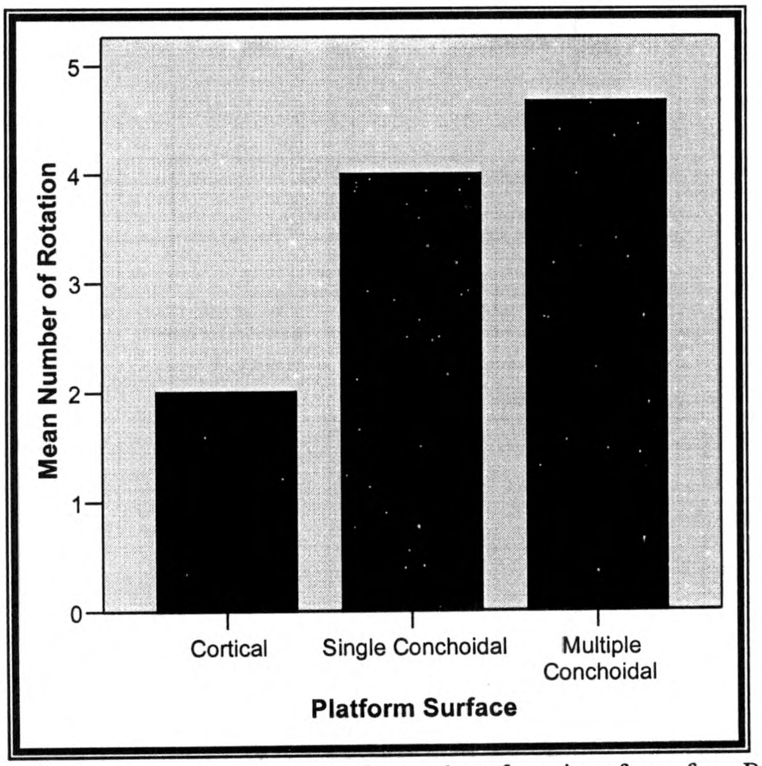

Figure 4.26.1. Bar graph for platform surface by number of rotation of core from Benkaneri.

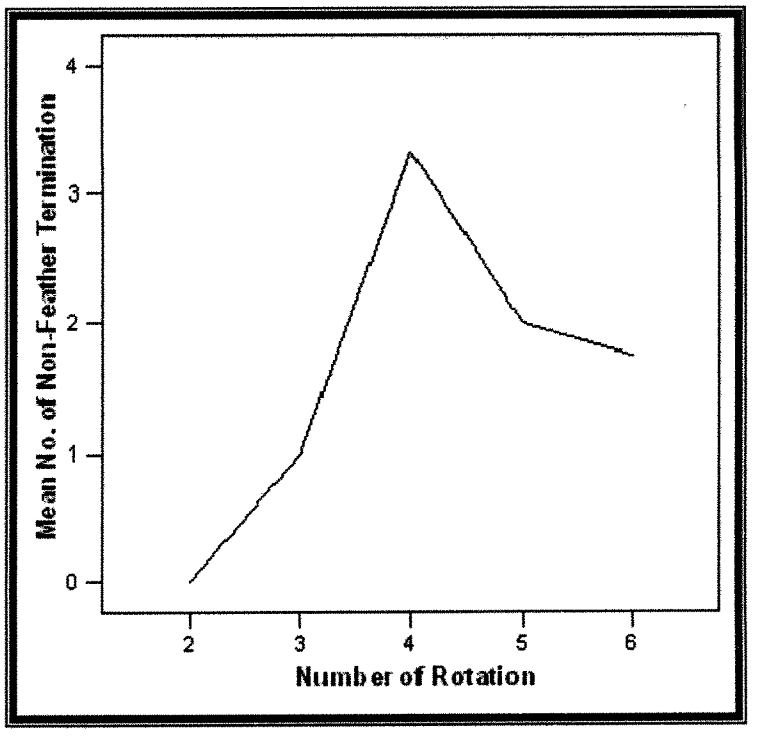

Figure 4.26.2. Line graph for number of rotation of core versus mean number of non-feather termination from Benkaneri.

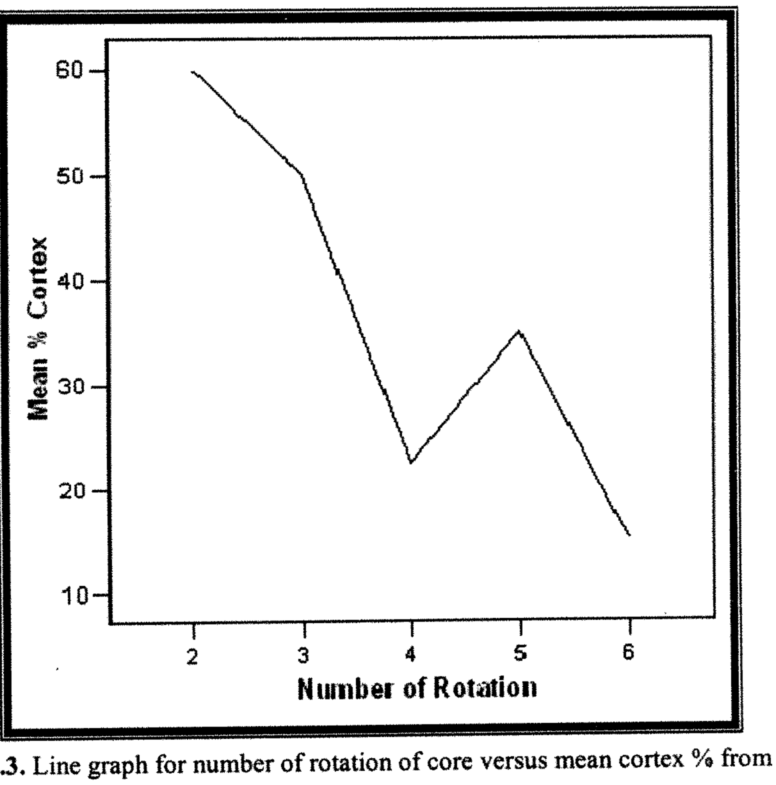

Figure 4.26.3. Line graph for number of rotation of core versus mean cortex % from Benkaneri.

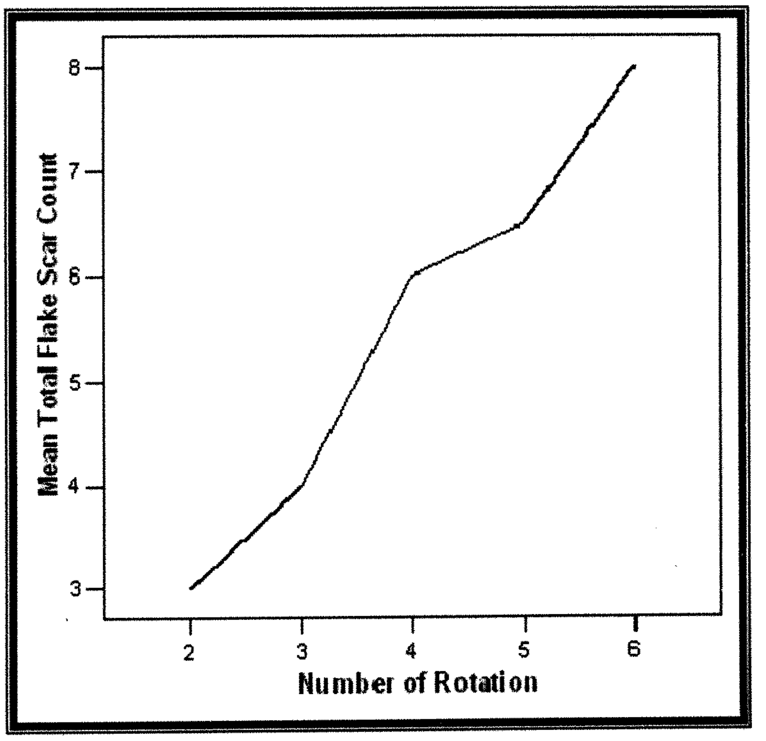

Figure 4.26.4. Line graph for number of rotation of core versus mean total number of flake scar count from Benkaneri.

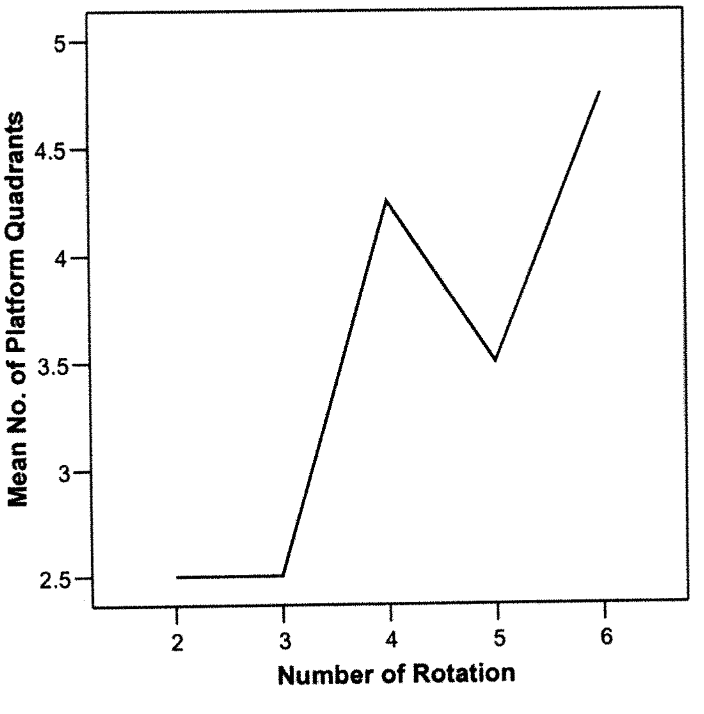

Figure 4.26.5. Line graph for number of rotation of core versus mean number of platform quadrants from Benkaneri.

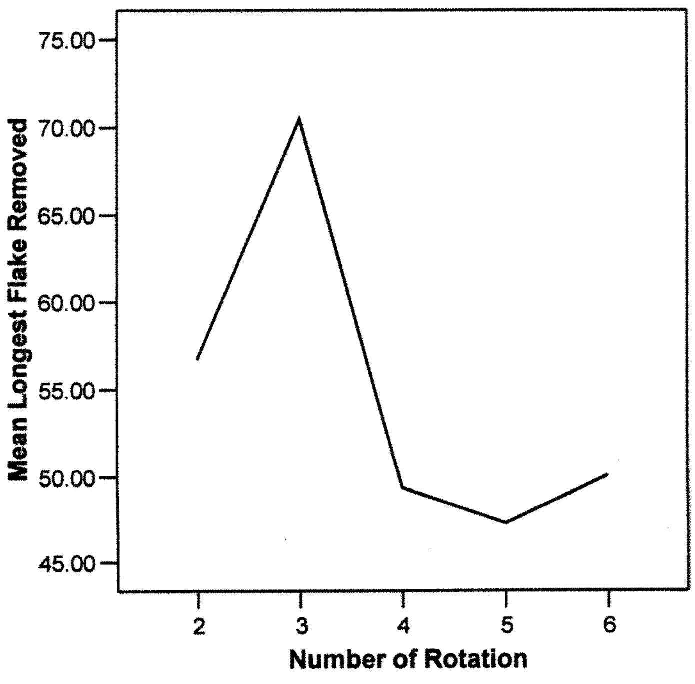

Figure 4.26.6. Line graph for number of rotation of core versus mean longest flakes removed from Benkaneri.

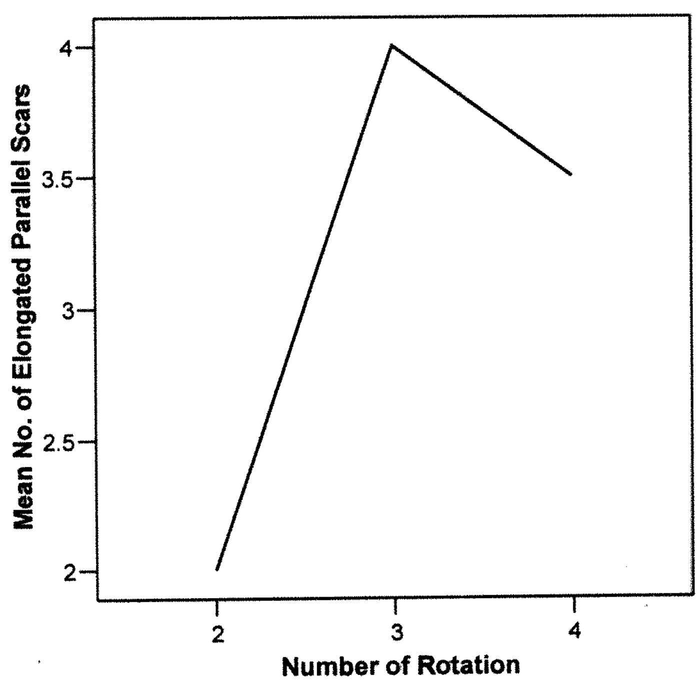

Figure 4.26.7. Line graph for number of rotation of core versus mean number of elongated parallel scar from Benkaneri.

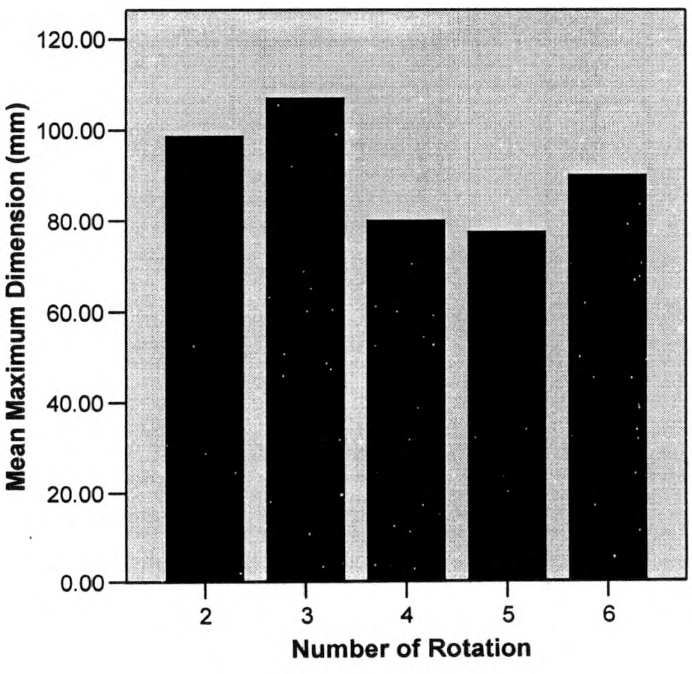

Figure 4.26.8. Bar graph for number of rotation of core versus mean maximum dimension from Benkaneri.

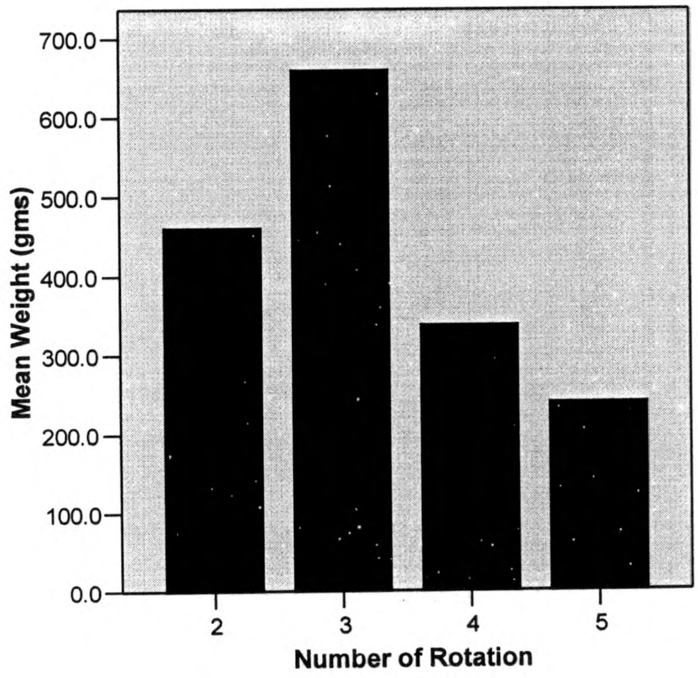

Figure 4.26.9. Bar graph for number of rotation of core versus mean weight from Benkaneri.

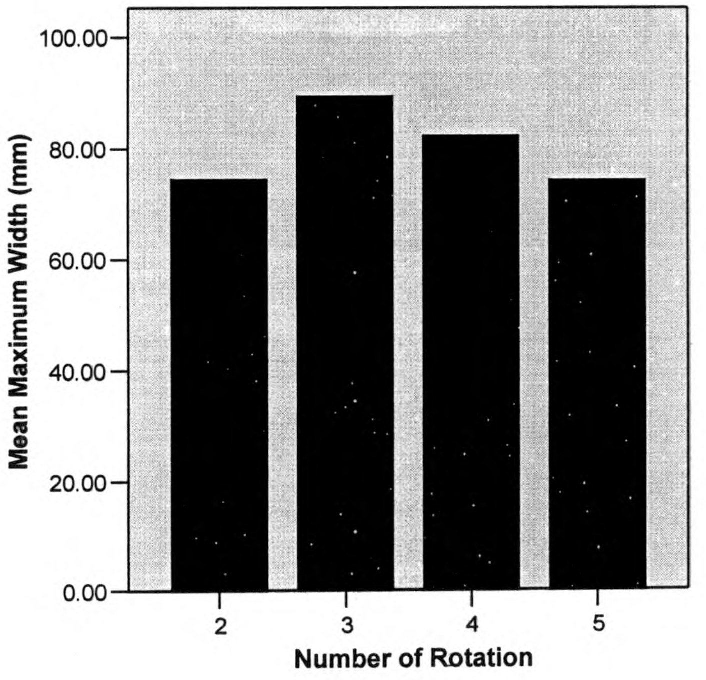

Figure 4.26.10. Bar graph for number of rotation of core versus mean maximum width from Benkaneri.

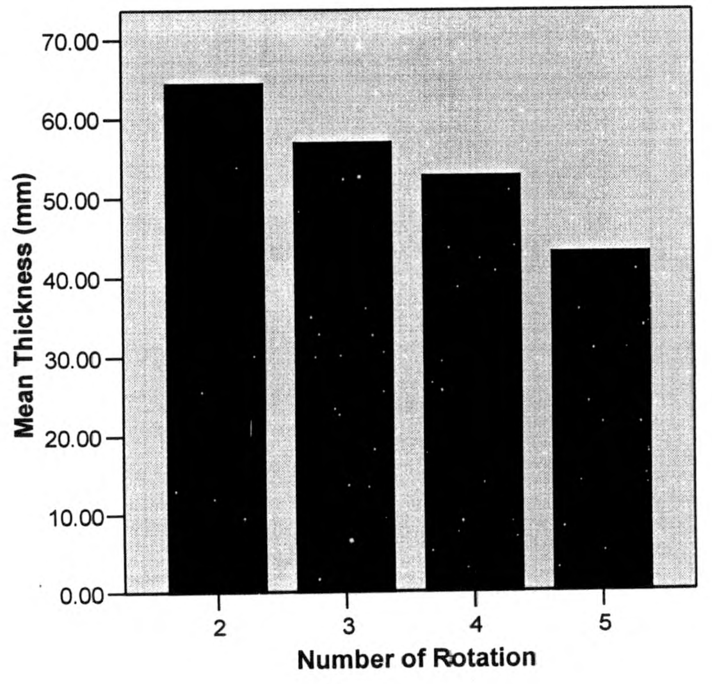

Figure 4.26.11. Bar graph for number of rotation of core versus mean thickness from Benkaneri.

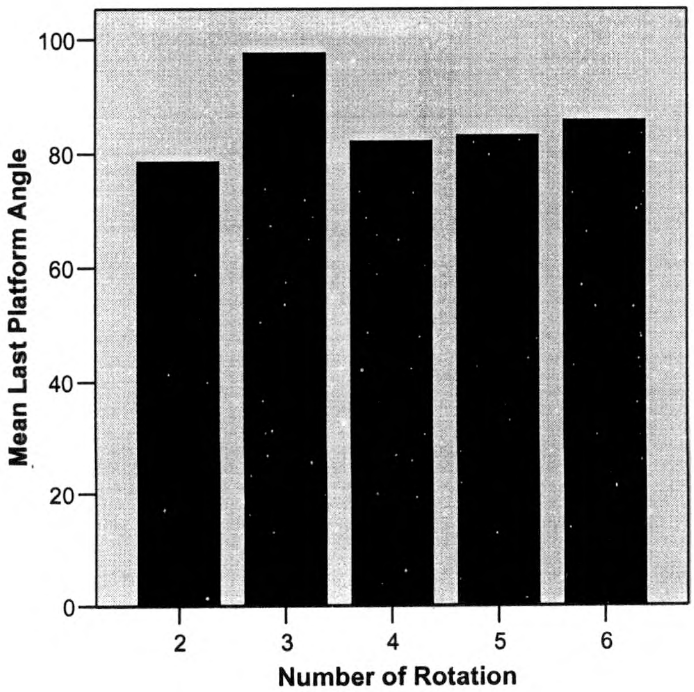

Figure 4.26.12. Bar graph for number of rotation of core versus mean last platform angle from Benkaneri.

Number of variables plotted against increasing core size

When number of variables was plotted against increasing core size, many interesting facts were came forward which throws light on the effect of reduction on the morphology of cores. Core with cortical platform has the highest mean core size, then comes multi conchoidal platform and the lowest core size was observed in the cores which had single conchoidal platform (Figure 4.26.13). When number of rotation (Figure 4.26.16), number of platform quadrants (Figure 4.26.19), scar>15mm (Figure 4.26.14), number of non-feather termination (Figure 4.26.17) and last platform angle increase (Figure 4.26.18) with the decrease in core size, indicating that, as reduction continues, the core size decreases as the number of rotation increases and this increase in number of rotation results in increase in number of platform quadrants, scar>15mm, number of non-feather termination and last platform angle.

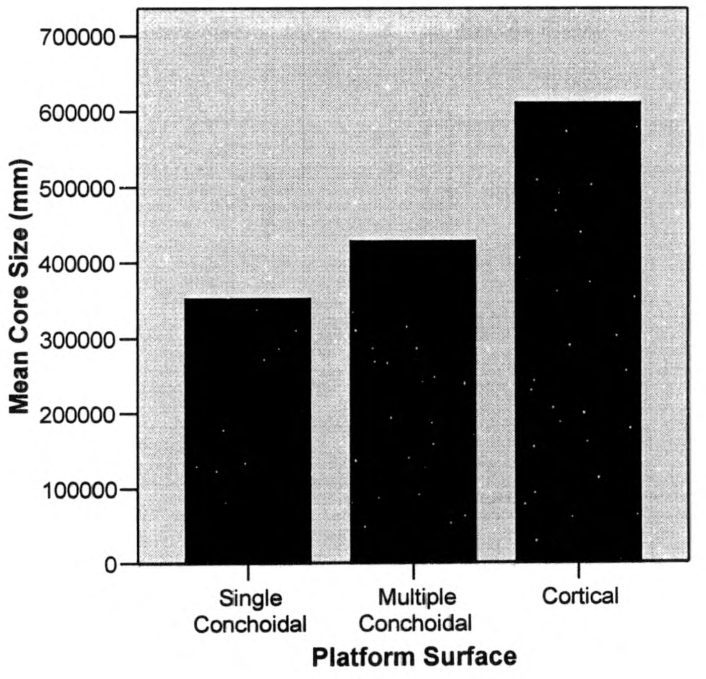

Figure 4.26.13. Bar graph for core size versus platform surface of cores from Benkaneri.

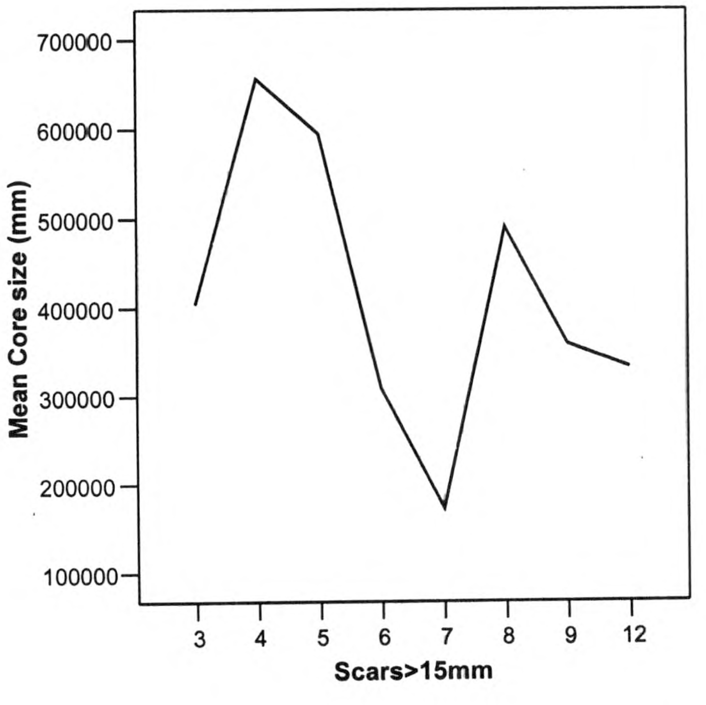

Figure 4.26.14. Line graph for core size versus scar>15mm of core from Benkaneri..

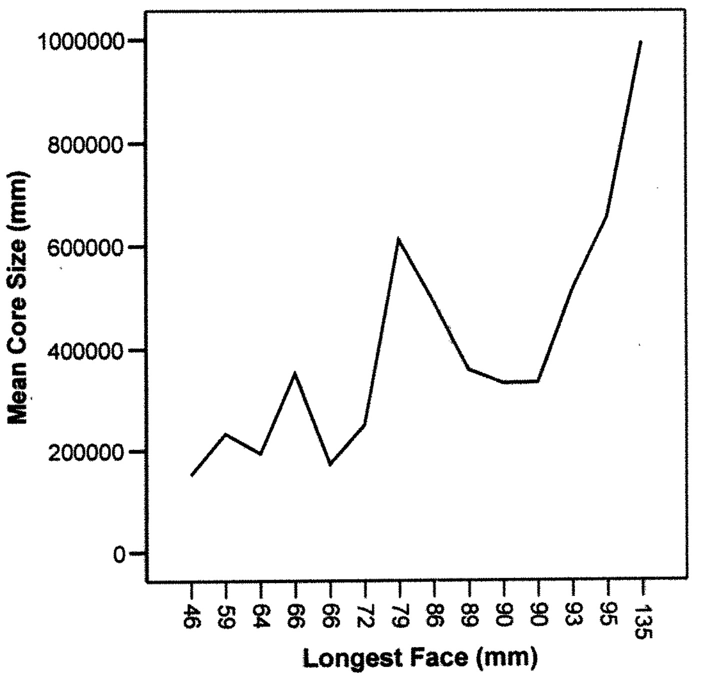

Figure 4.26.15. Line graph for core size versus longest face of core from Benkaneri.

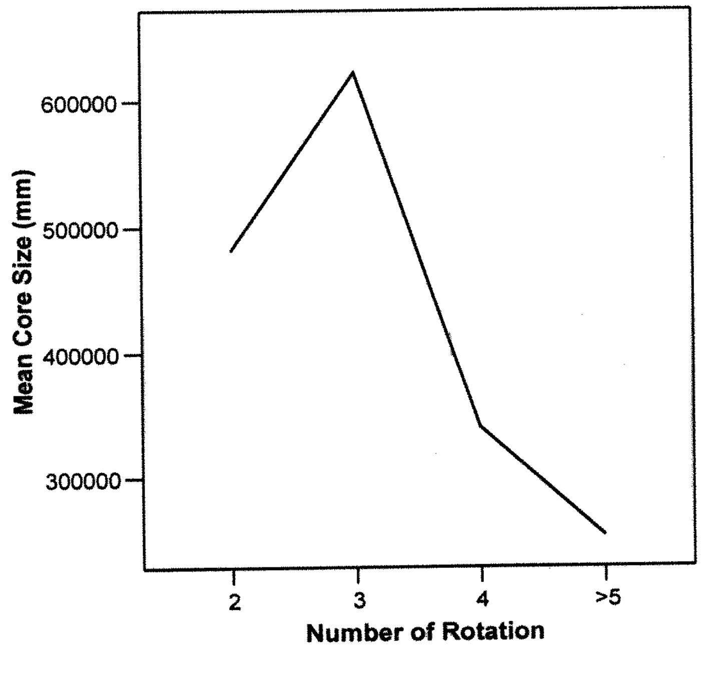

Figure 4.26.16. Line graph for core size versus scar>15mm of core from Benkaneri.

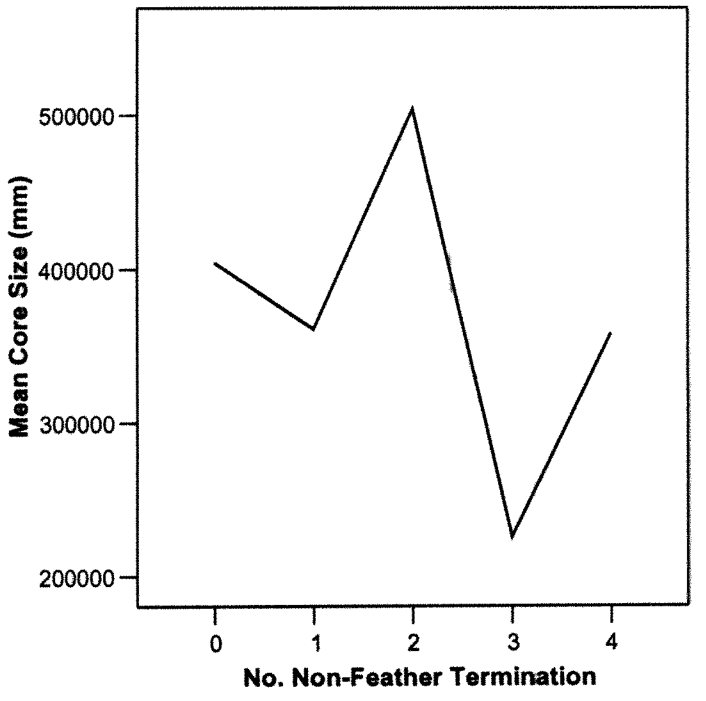

Figure 4.26.17. Line graph for core size versus number of non-feather termination of core from Benkaneri.

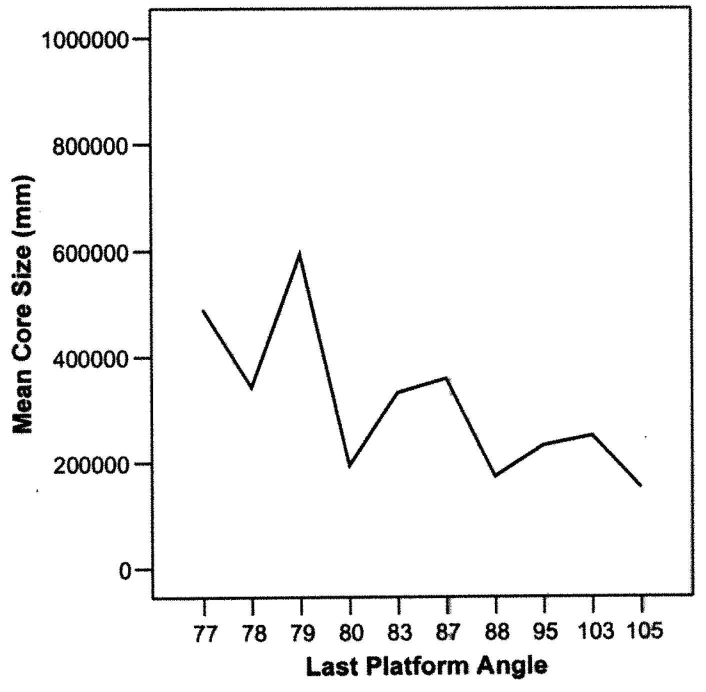

Figure 4.26.18. Line graph for core size versus last platform angle of core from Benkaneri.

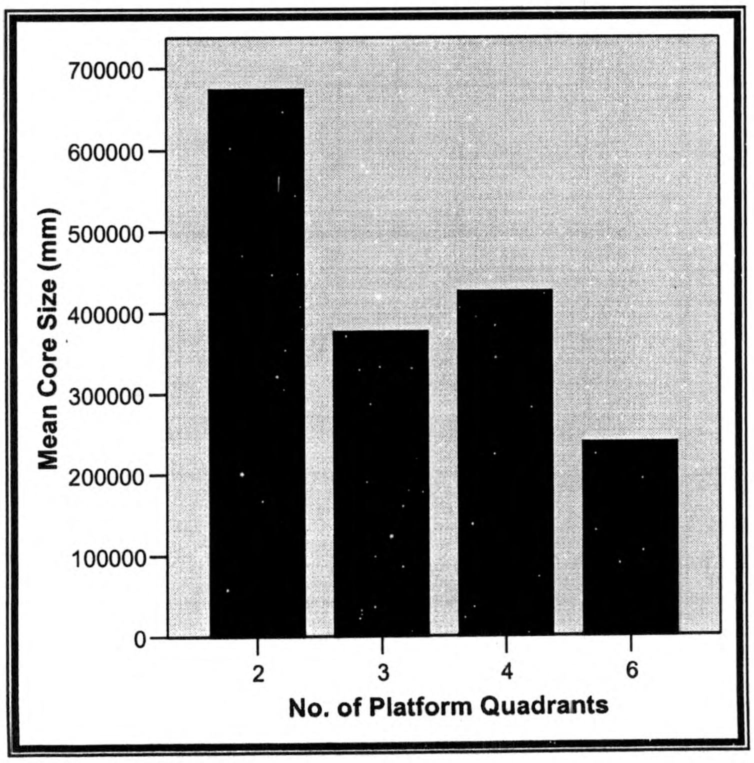

Figure 4.26.19. Bar graph for core size versus number of platform quadrants of core from Benkaneri.

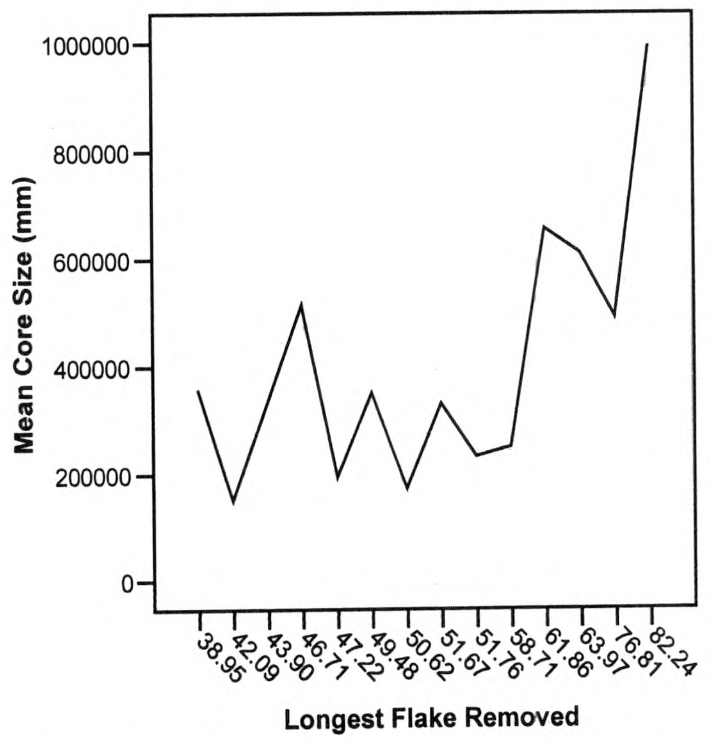

Figure 4.26.20. Linegraph for core size versus longest flake removed of core from Benkaneri.

4.27. Retouched tool typology at Benkaneri

This section will qualitatively and quantitatively explore retouched tool by analyzing its size and shape. Common metrical and non-metrical measurements are analyzed within and between the retouched tool types.

From a total of 38 flaked pieces, 5 are retouched tools, out of these 5, 2 (40%) are scraper and 3 (60%) are notched tool. All of these retouched tools were made from quartzarenites (quartzite) with 1/16 to 2 mm grain size. As these retouched tools were low in count (<10), no statistical analysis or any kind of comparison could be made. Only the general linear measurements for defining size and shape could be compared within the two types of retouched tools.

4.28. General metrical measurements for retouched tool types

Table 4.28.1., indicates that notched tools were longer (69.79 mm), wider (52.58 mm) and heavier (84.57 gms) than scraper, whereas scraper are thicker (15.45 mm) marginally than scraper. Notched tools vary considerably in maximum dimension, maximum width, thickness and weight than that of scrapers. Maximum of two notches were noticed from Benkaneri site, 1 notch was most common among these two and all these three notched tool type had a complex notch type. All scrapers and notched tool type were retouched on the dorsal side except one notched tool which was retouched at the ventral side.

Table 4.28.1. Mean, standard deviation and coefficient of variation of general metrical measurements for retouched tool types from Benkaneri.

Type	Variable	Mean	Std. Deviation	CV
Scraper	Maximum Dimension	47.41	6.31	0.13
	Maximum Width	37.32	9.34	0.25
	Thickness	15.14	6.09	0.40
	Weight	27.15	16.05	0.59
Notched	Maximum Dimension	69.78	34.79	0.50
	Maximum Width	52.58	14.78	0.28
	Thickness	15.45	8.21	0.53
	Weight	84.57	104.65	1.24

4.29. Analysis of debitage

Debitage is usually defined as an aggregation of unshaped, directly detached pieces resulting from percussion blows against another stone (Andrefsky 1998). Within lithic technological organization, the term usually refers both to the results of various reduction sequences that are directly the outcome of intended tool-making and to the unconscious results of producing miscellaneous chipped items.

Debitage comprised of complete flakes, broken flakes and flaked pieces. Present analysis is based on complete flakes. From a total 126 artifact collected from Benkaneri, 87 were debitage and out of these 87 debitage 37 (42.5%) are complete flake and 50 (57.5%) are broken flake. All debitage were made from quartzarenites (quartzite) with 1/16 to 2 mm grain size, except 1 which was made on sandstone, having >2 mm grain size.

Table 4.29.1. Frequency of debitage from Benkaneri.

Artifact Types		Counts	Percentage
Debitage	Complete Flake	37	42.5
	Broken Flake	50	57.5
Total		87	100

4.30. Non-metrical attributes recorded for core types

Common non-metrical attributes were recorded for debitage (non-metrical are explained in the methodology section of this thesis). Simple bar plots and simple tables were used in order to explain these non-metrical attributes.

Cortex type

Table 4.30.1., shows the preference for selection of the natural clasts by the hominins at this particular site Benkaneri. From Benkaneri a total of 37 complete flakes were collected and among them 18 had information on the presence of cortex type, in which, 9 were made on angular types, 4 on sub-angular,3 on sub-rounded and remaining 2 on indeterminate. Therefore, at this site the hominins were targeting for angular clast than other clast types (Figure 4.30.1).

Table 4.30.1. Frequency of cortex type for complete flakes from Benkaneri.

Cortex Type	Frequency	Percent
Angular	9	50
Sub-Angular	4	22.2
Sub-Rounded	3	16.6
Indeterminate	2	11.1
Total	18	100

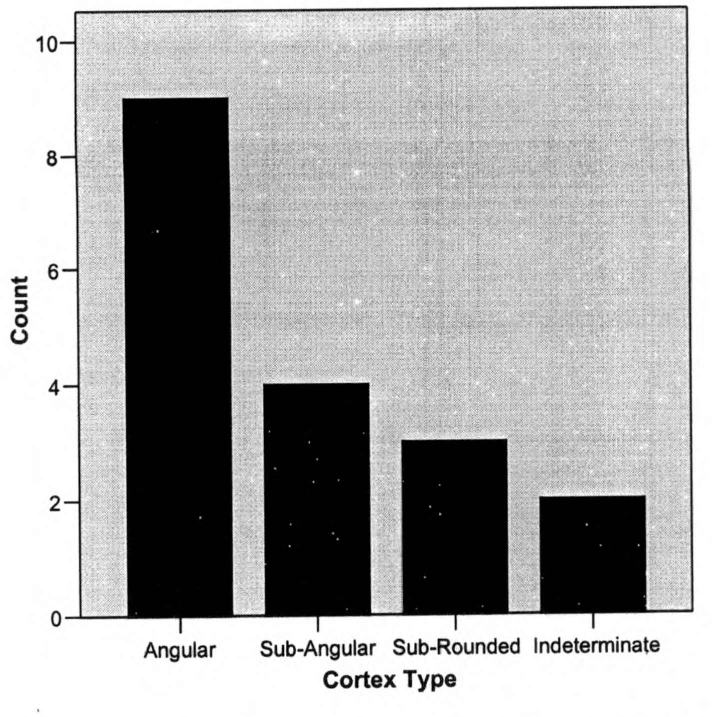

Figure4.30.1. Bar graph of cortex type for complete flakes from Benkaneri.

Cortex location.

Table 4.30.2., provides information on the cortex location. Out of 37 complete flakes, only 18 complete flakes holds the information of cortex location, out of these 18 complete flakes, 12 had cortical presence on the dorsal surface, 3 flakes had information on the presence of cortex at both the surface (platform as well as dorsal surface) and remaining 3 had information on platform. Therefore, maximum number of complete flakes which were removed from the core at this site had cortical evidence on the dorsal surface.

Table 4.30.2. Frequency of cortex location for complete flakes from Benkaneri.

Cortex Location	Frequency	Percent
Dorsal	12	66.6
Platform	3	16.6
Both	3	16.6
Total	**18**	**100**

Platform surface.

Six types of platform surface (cortical, single conchoidal, dihedral, multi conchoidal, focalized (punctiform) and crushed) were noticed from the collection of 37 complete flakes at this site.

Table 4.30.3. Frequency of platform surface for complete flakes from Benkaneri.

Platform Surface	Frequency	Percent
Cortical	5	13.5
Single Conchoidal	17	45.9
Dihedral	5	13.5
Multiple Conchoidal	1	2.7
Focalised (Punctiform)	7	18.9
Crushed	2	5.4
Total	**37**	**100**

Table 4.30.3., reveals the on different types of platform surface at this site. Among 37 complete flakes, 17 of them had single conchoidal platform surface, 7 had focalized type platforms, 5 had cortical types, another 5 had dihedral types, 2 had crushed types and remaining 1 had multi conchoidal platform type. Hence, the most common platform type at this site was single conchoidal and focalized type of platform surface. Table 4.30.3., describes that the higher count of flakes with single conchoidal platform surface that were collected from this site, were reduced only from the core which had single conchoidal platform.

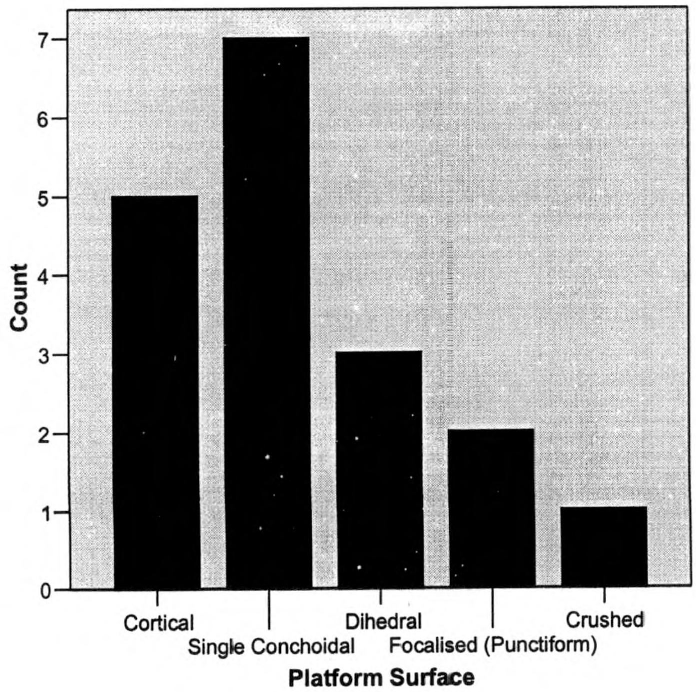

Figure 4.30.2. Bar Graph of platform surface for complete flakes from Benkaneri.

Termination type.

Two types of termination (feather and hinge) were observed from the total collection of 37 complete flakes at this site and out of these 37 complete flakes, 36 were feather termination types and 1 was hinge type.

Table 4.30.4. Frequency of termination types for complete flakes from Benkaneri.

Termination Type	Frequency	Percent
Feather	36	97.3
Hinge	1	2.7
Total	37	100

4.31. General metrical measurements for debitage

Complete flake provided a lot of information on the flaking aspects at this site. Length provides information on the size of core from where these flakes have been removed, while other aspects like cortex percentage, cortex type, platform surface, platform size and dorsal scar count, when combined in right way it gave the reduction sequence of core from which these flakes were removed. Figure 4.31.1., shows that the mean value for length is different to each other. The mean value length is 69.4 mm. The mean value for maximum width is 60.8 mm and for the

thickness is 22.4 mm (Figure 4.31.2). Variation within in the length (S.D=24.7) and maximum width (S.D=20.1) are high, whereas, thickness (S.D=9.5) show very little variation within the complete flakes.

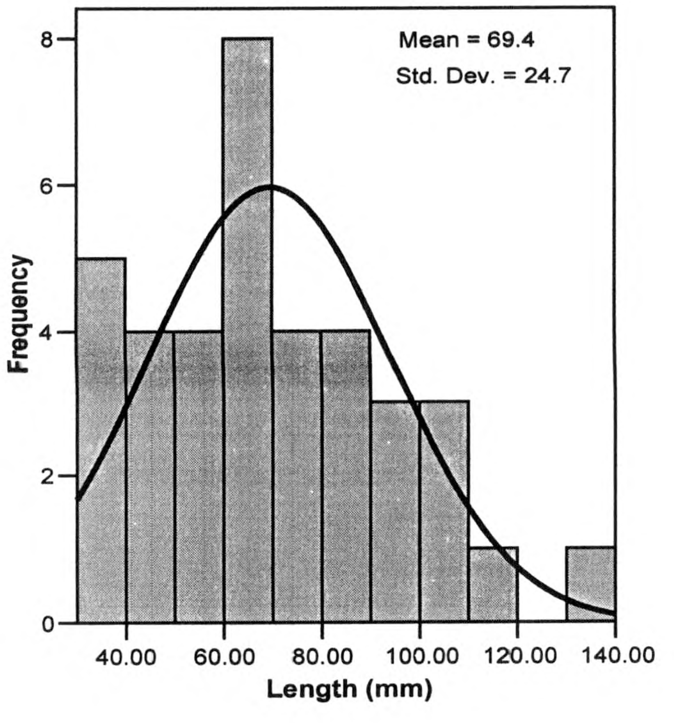

Figure 4.31.1. Histogram of length for complete flakes from Benkaneri.

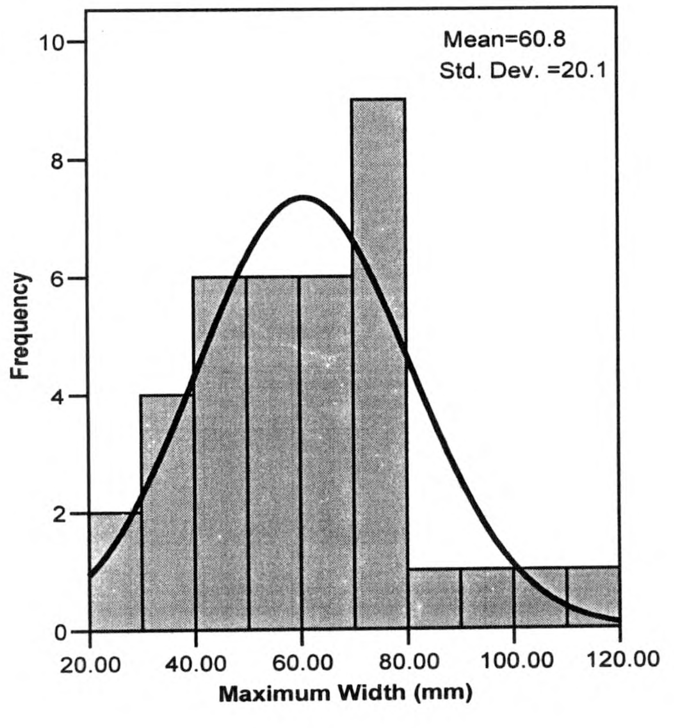

Figure 4.31.2. Histogram of maximum width for complete flakes from Benkaneri.

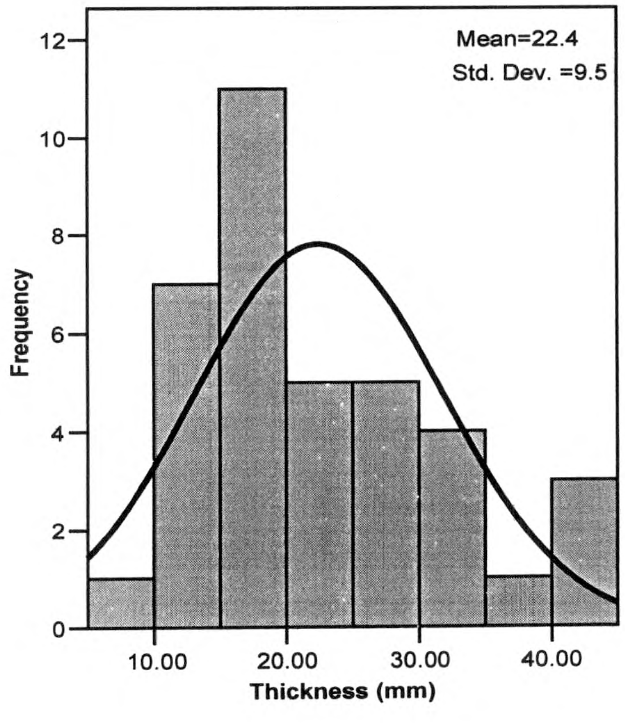

Figure 4.31.3. Histogram of thickness for complete flakes from Benkaneri.

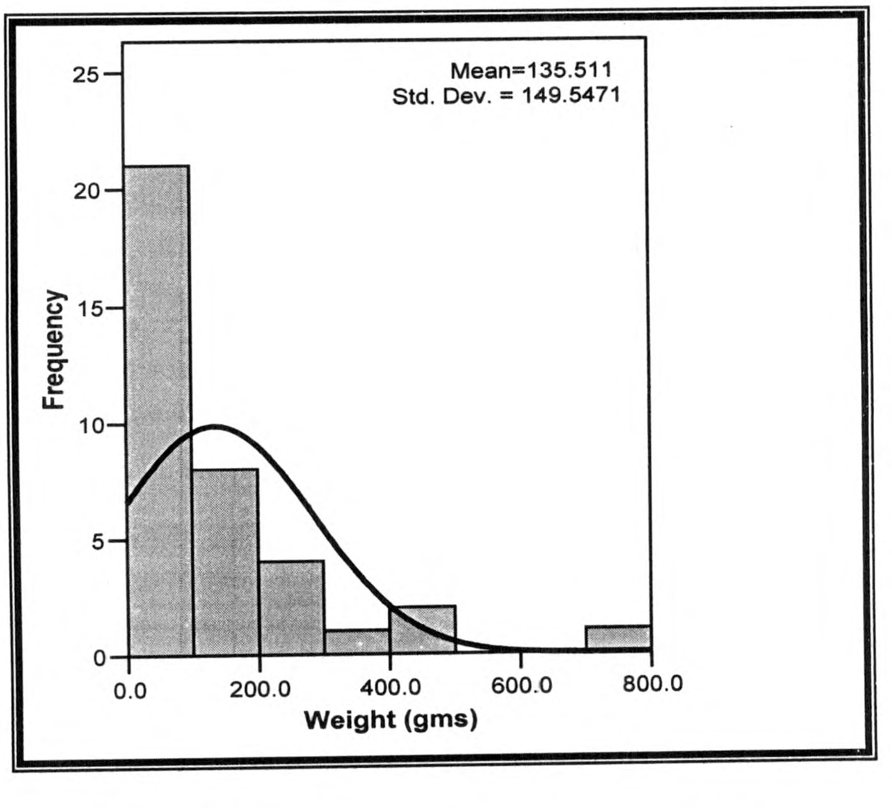

Figure 4.31.4. Histogram of weight for complete flakes from Benkaneri.

Breakdown of complete flake

Table 4.31.1., is a breakdown of complete flake length into 30 mm intervals and this kind of division of complete flakes into size intervals, can provide an assessment of the size range of individual flakes. Complete flakes that were collected from this site are 38 in numbers, among them, 17 were in 61 to 90 mm size, 13 were in 31 to 60 mm size, 6 were in 91 to 120 mm size and from remaining 2 which were in the least number at this site, 1 was in >121 mm size range and other 1 was in >0-30 mm size range. Majority of complete flakes were in between 31 to 90 mm range and others were in least count.

Table 4.31.1. Frequency of length categories from Benkaneri.

Breakdown	**Total**
>0-30 mm	1 (0.02)
31-60	13 (34.2)
61-90	17 (44.7)
91-120	6 (15.8)
>121	1 (0.02)
Grand Total	**38**

4.32. Comparison between made between natural clasts and flaked piece types from Benkaneri

Table 4.32.1., is a comparison made between natural clast with flaked piece types in order to find whether these natural clast were used to manufacture large cutting tools, choppers or retouched tools at Benkaneri. The natural clasts that were collected from this site are longer than other flaked piece types like large cutting tools (122.60±40.79 mm), cores (90.55±20.61 mm) and the shortest are retouched tool type (60.83±27.67 mm). Highest mean length value (181.65±109 mm) in natural clast shows much variation in the length (CV=0.60), (see, Table 4.32.1). Hence, the highest mean length of natural clast and the next higher mean length in large cutting tool type, indicates that, these natural clasts that were collected and analyzed from the transect laid at Benkaneri, might have been used to manufacture large cutting tool type. Whereas, cores and retouched tool types have greater differences in length, if they are compared to the length of natural clast.

Table 4.32.1., also reveals that natural clast have higher mean width value (106.62±55.21 mm) than large cutting tools (81.07±22.54 mm), cores (79.55±16.04 mm) and retouched tools (46.47±14.18) and these natural clast show higher variation

within them (CV=0.52). As natural clast type are followed by large cutting tools (81.07 mm), cores (79.55 mm) and retouched tools (46.47 mm) which are narrowest among all other tool types (see, Figure 4.32.2). As seen, from Figure 4.32.2., higher mean width value in natural clast and the next highest mean width value for large cutting tool types indicates that these natural clasts which were collected and analyzed from this site, might have been used to manufacture large cutting tools. When, the thickness and weight are compared between natural clast type and flaked piece types, they also show that mean thickness and weight value for natural clast are higher than that of flaked piece types, but the mean thickness of the core was higher (53.30 mm) than that of large cutting tool (47.97 mm).

Hence all this indicates that large cutting tools at this site were made from natural clast.

Table 4.32.1. Mean, standard deviation and coefficient of variation of general metrical measurements for natural clast type and flaked piece typed from Benkaneri.

Variable	Type	Mean	Std. Deviation	CV
Maximum Dimension	Natural Clast Type	181.65	109.00	0.60
	Large Cutting Tool Type	122.60	40.79	0.33
	Core	90.55	20.61	0.23
	Retouched	60.83	27.67	0.45
Maximum Width	Natural Clast Type	106.62	55.21	0.52
	Large Cutting Tool Type	81.07	22.54	0.28
	Core	79.55	16.04	0.20
	Retouched	46.47	14.18	0.31
Thickness	Natural Clast Type	70.55	51.45	0.73
	Large Cutting Tool Type	47.97	13.08	0.27
	Core	53.30	9.20	0.17
	Retouched	15.32	6.56	0.43
Weight	Natural Clast Type	1829.72	1482.22	0.81
	Large Cutting Tool Type	512.37	397.04	0.77
	Core	383.25	243.14	0.63
	Retouched	61.60	80.80	1.31

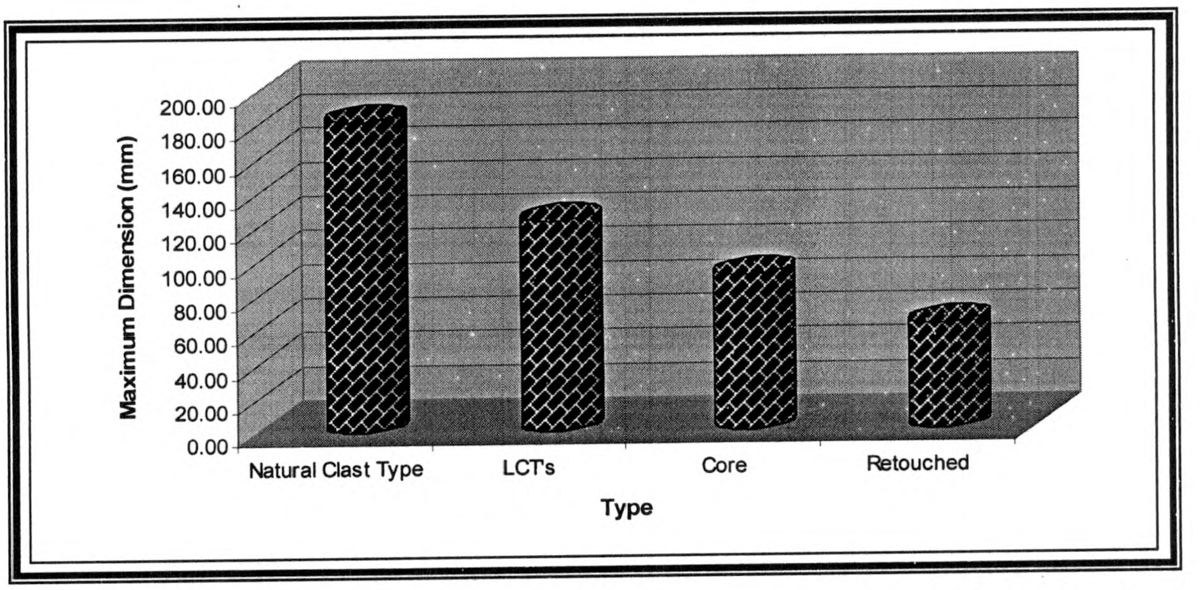

Figure 4.32.1. Bar graph of maximum dimension for natural clast type and flaked piece from Benkaneri.

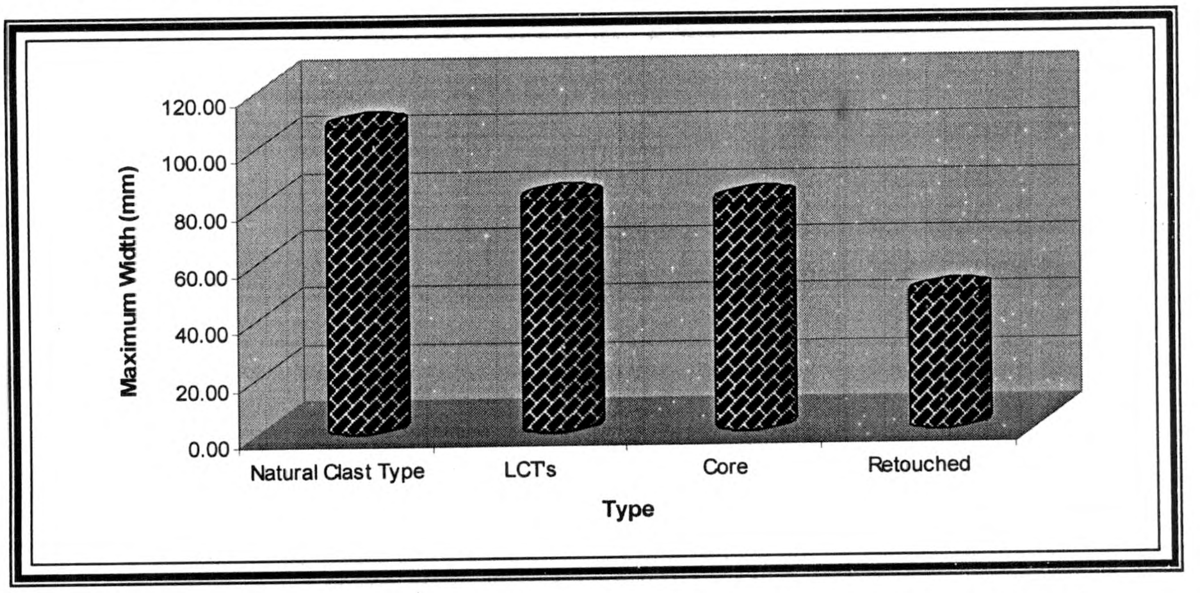

Figure 4.32.2. Bar graph of maximum width for natural clast type and flaked piece from Benkaneri.

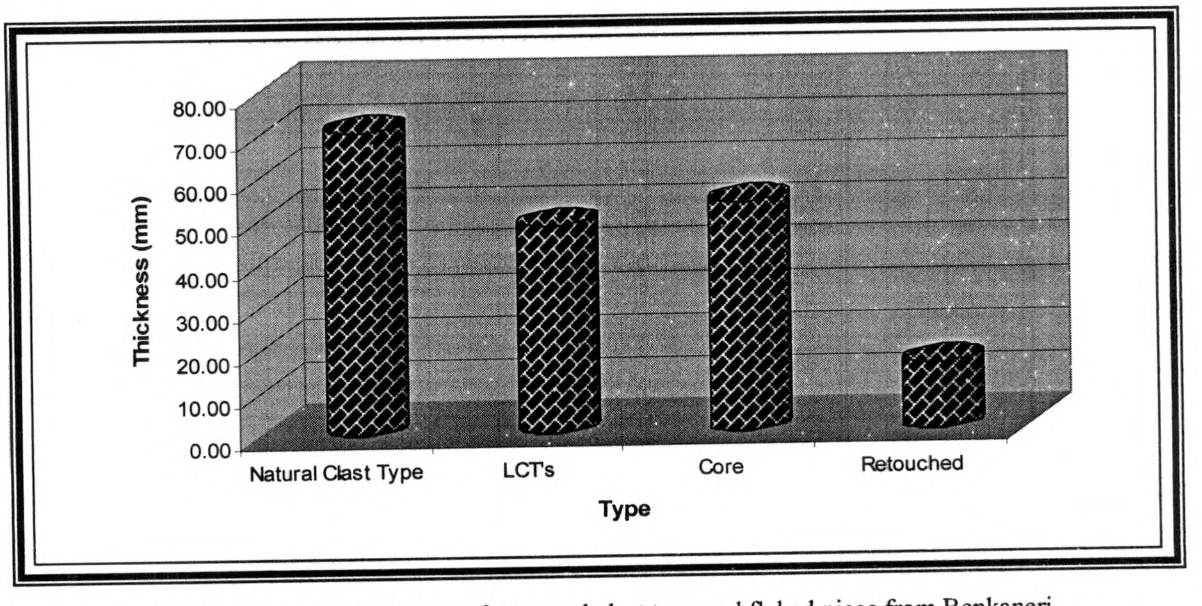

Figure 4.32.3. Bar graph of thickness for natural clast type and flaked piece from Benkaneri.

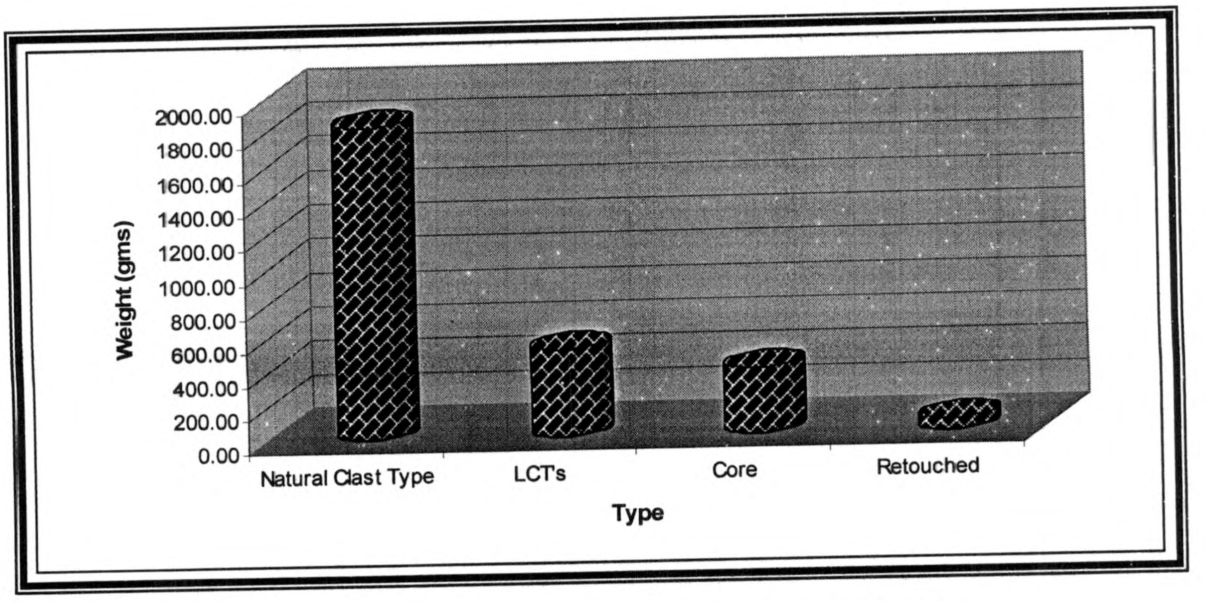

Figure 4.32.4. Bar graph of weight for natural clast type and flaked piece from Benkaneri.

4.33. Site description of Lakhmapur: Lat: 75°37′ E and Long: 15° 52′ N

There are two separate localities in this site namely Lakhmapur West and Lakhmapur East. These two separate areas were chosen for excavation by M. D. Petraglia, Joseph Schuldenrein and Ravi Korisettar (Petraglia *et al.*, 2003). Lakhmapur West is 1 km northwest of the village and Lakhmapur East is 2 km northeast of the village and both sites were noticed on the northern slopes of the quartzitic ridge of the southern margin of Kaladgi Basin (Figure 4.33.1).

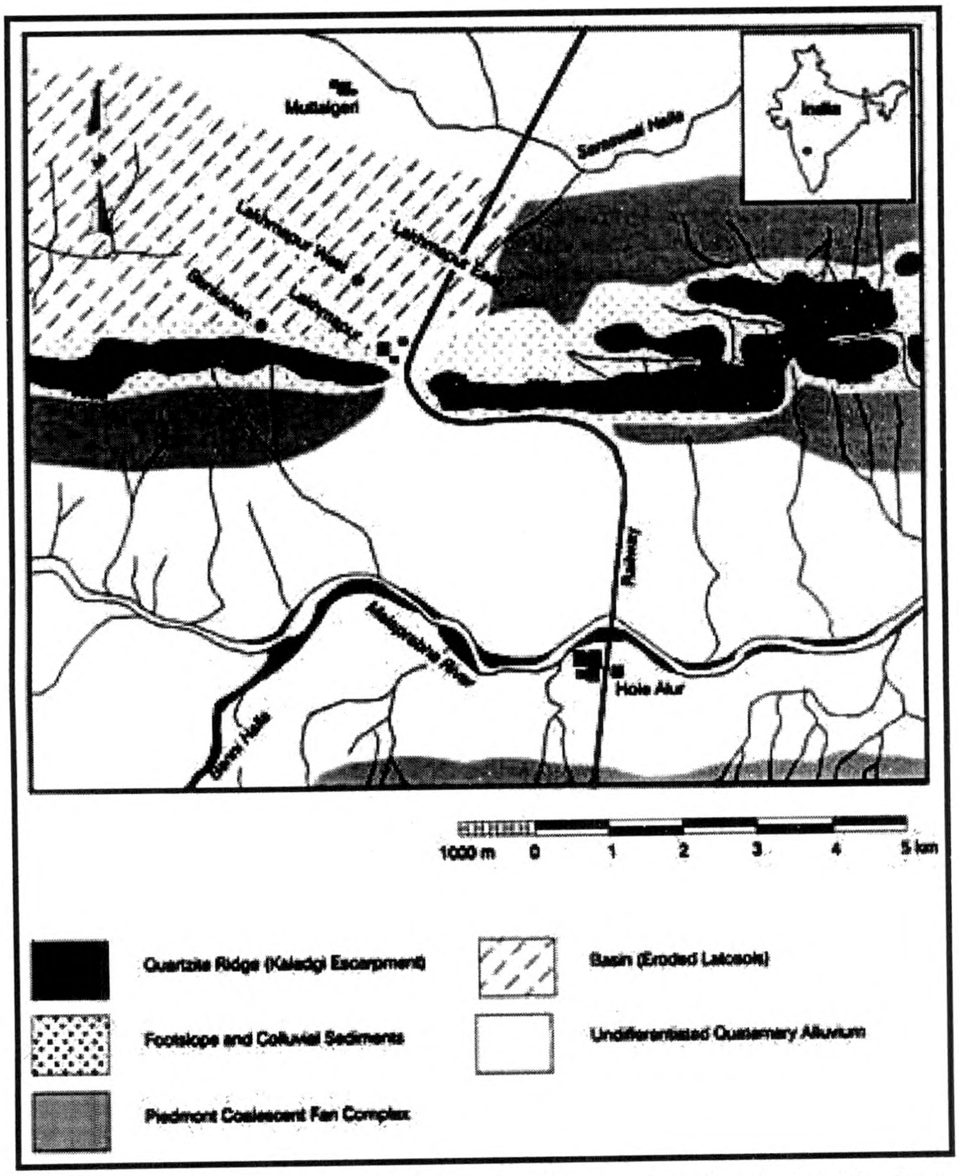

Figure 4.33.1. Surface geology of Lakhmapur and Benkaneri Archaeological Site Complex. Principle Palaeolithic sites are noted by circles. Note that Lakhmapur West, Lakhmapur East are located along different landfoem segments (adopted from Petraglia *et al.*, 2003).

The Kaladgi escarpment consisted of east-west trending quartzarenites (quartzite) ridge, rising to a crest of 730 m, with local plateau elevations ranging from 600-650 m. Palaeolithic artifacts can be noticed over a 10 km stretch along the northern side of the east-west trending ridge. The surface distribution of artifacts was accompanied by buried artifacts as seen from the modern burrow pits and road cuttings dug by locals. The site Lakhmapur has piedmont coalescent fan complex with the drainage lines flow into a tributary of the Malaprabha, the Saraswati Halla and these fans drained the foothills of the Kaladgi escarpment. Near the foothill on the north trending coalescent fans were capped by colluvium. The northern slope of

the north and west ridge merged with an extensive laterised peneplain surface. The topography became increasingly subdued as the peneplain graded down to a lower-lying basin segment, where elevations were at their lowest, ca. 560-540m (Petraglia *et al.*, 2003). The laterised peneplain was noticed exposed and buried in segments due to continuous erosion. The most extensively exposed surface was an eroded latosol and this latosol were discontinuously buried by a 0.1-0.4 m thick layer of black clay, apparently representing a residual deposit of former drainages (Petraglia *et al.*, 2003).

Lakhmapur West

To the northwest of the village artifacts were seen buried on the wall of the modern burrow pits dug by the locals. The exposed wall extended more than 100 m north-south and 50 m east-west in direction. In order to examine the deposition of artifact-bearing surface, four separate blocks, composed of a total of thirteen one-meter square units were placed. From these test pits one block, consisting of five one-meter units was particularly productive as it produce a diverse assemblage comprising tools and debitage (Petraglia *et al.*, 2003).In order to characterize the natural clast a transect was laid down from the top of the hill to the foot of the hill.

Table 4.33.1. Stratigraphy of Lakhmapur West

Unit	Description
I	**Upper latosol (0.0-0.2 m)** 2.5 YR4/6 loose matrix of poorly sorted and gritty fine sands plowed at top half of deposit; Middle Palaeolithic artifacts. Interspersed with firm, small, sub-angular blocky clays; organic staining; diffuse and wavy lower boundary.
II	**Lower latosol (0.2-1.2 m)** 2.5 YR4/4 to 2.5 YR4/6 cohesive matrix of moderately compacted (compound) moderate to coarse peds of angular blocky clay-sands; pisolitic ferricrete Nodules (ca. 5 percent by volume) interspersed in matrix but increase with depth; ferriargillaceous coatings around clay peds; clear and wavy lower boundary. Latosol interdigitates with calcareous matrix and tufaceous blocks.
III	**" Stone line" (1.2-1.5 m)** 2.5 YR4/4 clast supported porous matrix of stones (ca. 90 percent by volume) with loose to firmly packed sands, silts and clays; Acheulian assemblages, stones are quartzite artifacts (6-90 mm along major axis) and pisoliths, irregularly and weakly cemented; nodular pisoliths are lustrous and slightly pitted; sharp and smooth lower boundary.
IV	**Upper nodular laterite and basal tufa (1.5-3.2 m)** 2.5 YR4/6 coarse sands, dense ferricrete filaments and pisoliths (ca. 65 percent by volume), and quartzite debitage, artifacts and debris; matrix is laterally and vertically interdigited to base with discontinuous tufa blocks and tufaceous cements (5 YR6/6) and concretions (7-12 mm) ed around root casts (up to 40 percent of matrix by volume); clear and wavy lower boundary.
V	**Lower indurated laterite (3.2->4.8 m at base of exposure)** 10 YR4/6 cemented beds of lateritic sands and decaying rubble from underlying bedrock (saprolite); beds inclined at 32° to SSE.

Stratigraphic description's taken from Petraglia *et al.*, 2003.

Stratigraphic description of Lakhmapur West. The stratigraphic profile from Lakhmapur West sites showed a successive trend from Acheulian to Middle Palaeolithic assemblages, associated with particular sedimentary environments (Figure.4.33.1). A prominent feature of this profile was the semi-continuous "stone line" consisting of quartzite measuring 40-50 mm in diameter of which 15% were Acheulian artifacts (Unit III). Unit III was ca. 1.2 to 1.5 m below surface and about 20-30 cm thick. The stone line was preserved between the indurated laterite (Unit V) and the lower latosol (Unit II), associated with tufaceous deposits (Unit IV). The cultural materials in Unit III were not separable (laterally or vertically) from the

Nodules (Figure 4.33.2) (Petraglia *et al.*, 2003). The Middle Palaeolithic artifacts were from the uppermost latosol.

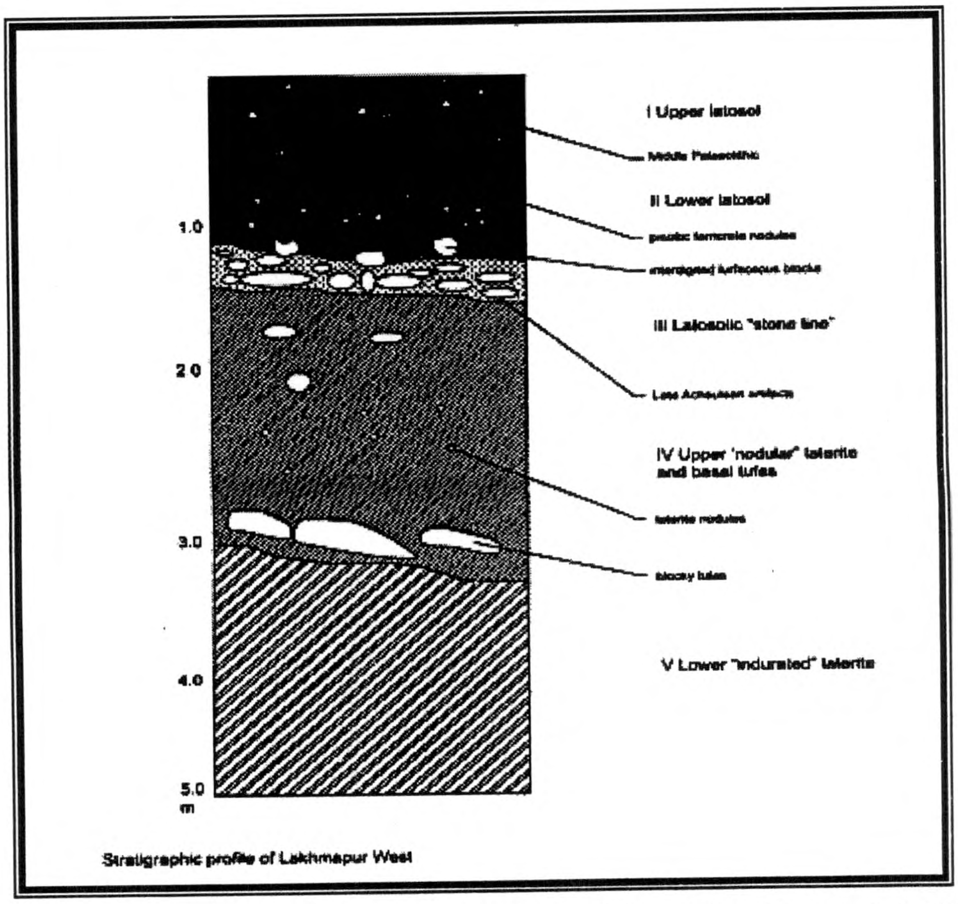

Figure 4.33.2. Stratigraphic Profile of Lakhmapur West (adopted from Petraglia *et al.*, 2003).

Lakhmapur East

Lakhmapur East is 2 km northeast of the village. Artifacts were noticed as a buried surface along a road cut at Lakhmapur East. The excavations were conducted at two separate areas namely Block I and II, along the distal (piedmont) margin of the lower peneplain. From this site six 1x1 m. sq. units were excavated in Blocks I and II (3 units each) (Table 4.33.2) (Petraglia *et al.*, 2003). Block I was located 1 km north of the ridge, at the interface of the footslope and the coalescent fan and Block II was placed 1.5 km north of the ridge, at the distal margin of the coalescent fan.

Table 4.33.2. Stratigraphy of Lakhmapur East, Block I

Unit	Description
I	**"Plow zone" in upper black clays (0.0-0.15 m)** 7.5 YR4/3 heterogeneous matrix of gritty sands and clays; structures are weak, sub-angular blocky; cobbles and stones abundant; roots are common and fibrous; occasional sedimentary Nodules (reworked from upslope soils); secondary carbonates ("kankars") at base; clear and smooth lower boundary.
II	**Black clay ("Palaeovertisol") (0.15-0.85 m)** 7.5 YR4/2 to 2.5 YR4/6 columnar to coarse prismatic, firmly structured black clays with thick (1-2 mm) sandy veins; few stones and roots; defused sedimentary inclusions (disaggregated ferricrete Nodules); abundant organic films/clay skins (organans); carbonate filled root casts at base; shrink swell structures account for diffuse artifacts; sharp and smooth lower boundary.
III	**Nodular laterite (0.85->1.20 m at base of exposure)** 2.5 YR4/4 to 4/6 medium to coarse friable to moderately cemented sands and consolidated clays with dense ferricrete filaments and pisoliths (ca. 35 percent by volume; 3-6 mm size range); extensive oxidation-reduction streaking (5 YR5/6) at ped interfaces. Laterite contains quartzite boulders.
IV	**Weathered Kaladgi Quartzite Bedrock**

Stratigraphic description adopted from Petraglia *et al.*, 2003.

Stratigraphic description of Lakhmapur East, Block.

The uppermost level from the excavation exposed a "black clay" resting uncomformably above a nodular laterite. The occurrence of Middle Palaeolithic artifacts extended from the "black clays" (Unit II) to the top of nodular laterite (Unit III). An uncalibrated radiocarbon date of 8,190±90 B.P. (Beta-104890) has been obtained from the "black clay", indicative of sedimentary reworking during the Early Holocene (Petraglia *et al.*, 2003). The artifacts from Unit II and Unit III were rounded in nature, due to the long term and continuous exposure weathering.

Table 4.33.3. Stratigraphy of Lakhmapur East, Block II

Unit	Description
I	**Upper latosol sediments (0.0-0.1 m)** 2.5 YR3/4 friable to weak, sub-angular blocky gritty and medium sands; abundant, well-rounded pebbles (2-5 mm); root casts with organic inclusions; sharp and smooth lower boundary.
II	**Lower latosol (0.1-0.35 m)** 2.5 YR3/3 weak sub-angular blocky to friable clay-sand with ferricrete and manganese filaments, largely disaggregated (2-7 mm size range, 25% by volume); clear, smooth lower boundary. High density of Middle Palaeolithic Artifacts; sharp artifact edges.
III	**Nodular laterite (0.35-0.5 m)** 2.5 YR3/4 weak to moderately sub-angular blocky clay sands, sub-horizontally bedded; loose to indurated matrix with ferricrete and manganese Nodules, densely packed; clear, wavy lower boundary.
IV	**Chert breccia and indurated laterite (>0.5 m)** Cemented and consolidated calcareous cement with spongy fabric.

Stratrigraphic description adopted from Petraglia *et al.*, 2003.

Stratigraphic description of Lakhmapur East, Block II

The Middle Palaeolithic artifacts were buried by a latosol (Unit II) and occurred in laterite (Unit III), resting on top of the indurated portion of the section (Unit IV).The artifacts occurred in high density (567 Artifacts/m^2) with a high percentage of small pieces of debitage (nearly 50 percent were less 2 cm) (Petraglia *et al.*, 2003).

4.34. Description of raw material types from Lakhmapur

This site yielded 5 varieties of raw material and they are quartzarenites (quartzite), quartz, chert, chert breccia and sandstone. Quartzarenites (quartzite) were the most extensive used at this site. These quartzarenites (quartzite) are exposed on the surface itself. Chert is found in Mahakut (approximately 4 km from the site) and Muttalgeri (approximately 15 km from the site). Chert breccia is also found in Mahakut area. Sandstones are found in Badami region which is 14 km from the site.

The quartzarenites (quartzite) of the Kaladgi series is the chief raw material used for manufacturing the tools in the prehistoric sites of Malaprabha valley. This quartzarenites (quartzite) is of Precambrian in origin. These quartzarenites (quartzite) are found in long and narrow ridge like hill chain which trends in a WNW-ESE direction. Quartzarenites (quartzite) are acidic in nature, since the rainfall is poor; the vegetative cover is likewise poor. The poor vegetation in this area has prevented chemical weathering, which otherwise would have resulted in the formation of a weathered surface for the area. This raw material possesses various shades of colours like red, pink, purple, grey, white, etc., and even this variety of quartzarenites (quartzite) has all the qualities that would have been normally required for the working of implements of a better type.

4.35. Degree of roundness of natural clasts

From the transect laid at Lakhmapur, a total of 11 natural clast were collected in which 7 (63.63%) were sub-angular and 4 (36.36%) were angular. The maximum value of the length (263.3 mm), width (181.9%), thickness (35.3%) and weight (3789%) is higher in sub-angular clast than angular clast (Table 4.35.1). The lower mean value and higher standard deviation clearly explains the variation between the roundness of clast i.e., angular and sub-angular types that were obtained.

Table 4.35.1. For roundness of clast inferred from the transect at Lakhmapur:

Degree of Roundness of natural clasts	Variable	N	Mean	Minimum	Maximum	Std. Deviation
Angular	Length	4	215.9	178.3	237.7	26.0
	Width	4	144.7	121.6	171.3	21.3
	Thickness	4	52.7	48.0	55.3	3.3
	Weight	4	2096.5	1430	3016	665.3
Sub-Angular	Length	7	190.3	128.4	263.3	52.5
	Width	7	128.1	78.7	181.9	39.0
	Thickness	7	52.0	35.3	70.9	11.8
	Weight	7	1611.3	379	3789	1188.2

4.36. Types of Natural Clasts

From the above table it was evident that the slab type were higher (8) in number than the heat spall (3). The mean length, width, thickness and weight value for slabs are higher than the heat spall types indicating the slabs are much longer, wider, thicker and heavier than the heat spall types. The heat spall varies considerably than slabs in all aspects like length, with, thickness and weight.

Table 4.36.1. Shows the length, width, thickness and weight of natural clasts types from Lakhmapur.

Types of Natural Clasts	Variable	Mean	Std. Deviation	CV
Slab	Length	214.1	37.1	0.17
	Width	137.0	29.5	0.22
	Thickness	55.4	8.2	0.15
	Weights	2017.1	997.9	0.49
Heat Spall	Length	161.0	47.1	0.29
	Width	126.4	49.4	0.39
	Thickness	44.0	7.7	0.18
	Weights	1176	970.7	0.83

4.37. Lithics from Lakhmapur

It is one of the most important sites among the sites in Malaprabha region. From this site a total of 989 artifacts were collected from the excavation. This site was sub-divided into two blocks namely Block I and Block II, further these blocks were subdivided into various localities like Locality I (IA, IB and IC), Locality II and Locality III. In each locality many Units were laid. From these units number of artifacts was collected.

In Locality IA, a total of 52 artifacts were collected from the excavation, out of these 52 artifacts, 44 (84.6%) were debitage and 8 (15.4%) were flaked piece. In Locality IB a total of 61 artifacts were recovered, out of this 42 (68.8%) were debitage and 19 were of flaked pieces. From the same Locality, but, from a different section i.e., IC, a total of 19 artifacts were recovered, out of this 19 artifact, 14 (73.7%) were debitage and only 5 (26.3%) flaked pieces were recovered from the excavation (Table 4.37.1).

From Locality II, a total of 59, out of these 59 artifacts, 40 (67.8%) were debitage and 19 (32.2%) were flaked piece. While, from Locality III a large number

of artifacts were recovered and they are 787 in total count. Out of these 787 artifacts, 737 (93.6%) were debitage and 57 (7.3%) were flaked piece (Table 4.37.1).

Table 4.37.1. Frequency of artifact types from Lakhmapur unit wise.

Locality	Unit	Spit	Artifact Type						Total
			Debitage		Flaked Piece Type				
			Complete Flakes	Broken Flakes	Large Cutting Tools	Chopper Tool	Core	Retouched Tool	
Surface				0	10	1	0	0	**11**
IA	1	1	9	17	1	0	4	1	**32**
	2	1	6	11	0	1	0	1	**19**
		2	0	1	0	0	0	0	**1**
IB	1	1	4	1	0	0	4	0	**9**
		2	4	2	0	0	5	0	**11**
	2	1	3	7	0	0	0	1	**11**
	3	1	9	9	2	0	0	2	**22**
		2	0	3	1	3	0	1	**8**
IC	1	1	5	9	1	0	4	0	**19**
II	1	1	8	6	1	0	0	0	**15**
		2	7	12	3	2	4	2	**30**
	2	1	0	0	0	0	3	0	**3**
		2	0	0	0	0	2	0	**2**
	3	1	0	0	0	0	1	0	**1**
	4	2	4	3	0	0	0	1	**8**
III	1	1	9	8	0	0	0	0	**17**
		2	79	172	1	0	3	2	**257**
	2	1	4	5	1	0	4	2	**16**
		2	59	197	3	0	2	9	**270**
	3	1	2	1	0	0	3	0	**6**
		2	53	148	3	0	10	5	**219**
	4	2	0	0	0	0	2	0	**2**
Total			**265**	**612**	**27**	**7**	**51**	**27**	**989**

4.38. Large cutting tool typology at Lakhmapur

This section will qualitatively and quantitatively explore the large cutting tools by analyzing its size and shape. Common metrical and non-metrical measurements are analyzed within and between the large cutting tool types.

From a total of 989 artifacts collected from Lakhmapur, 27 (2.7%) of them were large cutting tools and among these 27 large cutting tools, 9 (33.3%) were handaxes, 13 (48.1) were axe blank, 1 (3.7%) is cleavers, 1 (3.7%) is cleavers blank, 1 (3.7%) is assayed core, 1 (3.7%) is discoid and 1 (3.7%) is other miscellaneous (Table 4.38.1).

Table 4.38.1. Frequency of large cutting tools from Lakhmapur.

Large Cutting Tool	Frequency	Percent
Handaxe	9	33.3
Cleaver	1	3.7
Axe Blank	13	48.1
Cleaver Blank	1	3.7
Assayed Core	1	3.7
Discoid	1	3.7
Other & Miscellaneous	1	3.7
Total	**27**	**100**

4.39. Non-metrical attributes recorded for large cutting tools

Common non-metrical attributes were recorded for large cutting tools (non-metrical are explained in the previous section as well as in the methodology section of this thesis). Simple bar, box plots and simple tables were used in order to explain these non-metrical attributes.

Raw material and grain size types

From 27 large cutting tools, except 1 (11.1%) large cutting tool made on sandstone all (26) other large cutting tools were made from quartzarenites (quartzite). When large cutting tools were compared with grain size similar thing was noticed, as quartzarenites (quartzite) has 1/16 to 2 mm grain size they were in the majority and only one sandstone which has >2 mm grains size was minimum in percentage. From Table4.39.1and 4.39.2., its easy to make inference that quartzarenites (quartzite) with 1/16 to 2 mm grain size were the most preferred raw material to manufacture large cutting tools at this site.

Table 4.39.1. Frequency table for large cutting tools broken down by raw material from Lakhmapur.

Large Cutting Tool Type	Raw Material		Total
	Quartzarenites (quartzite)	Sandstone	
Handaxe	**8 (88.9)**	**1 (11.1)**	**9**
Cleaver	1 (100)	0 (0.0)	1
Axe Blank	13 (100)	0	13
Cleaver Blank	1 (100)	0	1
Assayed Core	1 (100)	0	1
Discoid	1 (100)	0	1
Other & Miscellaneous	1 (100)	0	1
Total	**26 (96.3)**	**1 (3.7)**	**27**

Table 4.39.2. Frequency table for large cutting tools broken down by grain size from Lakhmapur.

Large Cutting Tool Type	Grain Size		Total
	Rudeacuous (>2 mm)	Arenaceous (1/16 to 2 mm)	
Handaxe	1 (11.1)	8 (88.9)	9
Cleaver	0 (0.0)	1 (100)	1
Axe Blank	0 (0.0)	13 (100)	13
Cleaver Blank	0 (0.0)	1 (100)	1
Assayed Core	0 (0.0)	1 (100)	1
Discoid	0 (0.0)	1 (100)	1
Other & Miscellaneous	0 (0.0)	1 (100)	1
Total	**1 (3.7)**	**26 (96.3)**	**27**

Cortex type

From 27 large cutting tools, only 14 (51.8%) had information's on the cortex type. Out of these 14 large cutting tools, 4 were handaxes, 8 were axe blanks, 1 is an assayed core and another 1 is an others & miscellaneous. Out of these 4 handaxe, 3 were made from angular clast type and only one on indeterminate. Axe blanks are 8 in count, out of these 8, 6 were made from angular, 1 is made from sub-rounded and 1 is made from indeterminate. Assayed core which is 1 in count was made from sub-angular clast type and other miscellaneous which is also least in count (1) was made from angular clast type. From this table (Table4.39.3) it can be summarized that majority of large cutting tools were made on angular (10) and were followed by indeterminate (2), sub-angular (1) and sub-rounded (1).

Table4.39.3. Frequency of cortex type for large cutting tools from Lakhmapur.

Large Cutting Tool Type	Cortex Type				Total
	Angular	Sub-Angular	Sub-Rounded	Indeterminate	
Handaxe	3	0	0	1	4
Axe Blank	6	0	1	1	8
Assayed Core	0	1	0	0	1
Other & Miscellaneous	1	0	0	0	1
Total	10	1	1	2	14

Initial form

Handaxes, axe blanks, assayed core and other miscellaneous had information on the initial form, whereas, cleaver, cleaver blank and discoid had no information on the initial form. Slab, blocky, flake and indeterminate are the only four types, from which hominins at this site manufactured large cutting tools. Table 4.39.4., is tabulation for large cutting tool types by its initial form. From the Table 4.39.4., it is easy to understand that flake were in majority (13), followed by indeterminate (10), slab (3) and blocky (1) Handaxes which are 9 in count, from these 9 handaxes, majority (10) of them had very little information on the initial form, so they were grouped in indeterminate groups and other were made from flakes (2) and slab (1). Whereas, all (13) axe blanks had information on the initial form, out of these 13, 10 were made from flake, 2 on indeterminate and only 1 on slab. Cleaver (1) and discoid (1) which was collected from this site had little information on the initial form, so they are grouped into the indeterminate group and cleaver blank, which also has the least count (1), was made from flake. Assayed core which was collected from this site had been made from blocky clast type. It is clear that the majority of large cutting tools were made from flakes (13), others on indeterminate (10), slabs Among 27 large cutting tools, 9 were broken large cutting tools. Large cutting tool types had broken tools within them and they are handaxe (7) and axe blanks (2), remaining all other large cutting tools are complete. Out of these 7 handaxes broken, 5 broke at the tip and 2 at the butt end, while, for axe blank, 1 had broken tip and another 1 was broken at tip and butt end. Majority of large cutting tools broke at the tip; this indicates that hominins at this site gave excessive amount of pressure when they were reducing the specimen at the base or on the lateral sides of the specimen.

Table 4.39.4. Large cutting tools broken down by its initial form from Lakhmapur.

Large Cutting Tool Type	Initial Form				Total
	Blocky	Slab	Flake	Indeterminate	
Handaxe	0	1	2	6	9
Cleaver	0	0	0	1	1
Axe Blank	0	1	10	2	13
Cleaver Blank	0	0	1	0	1
Assayed Core	1	0	0	0	1
Discoid	0	0	0	1	1
Other & Miscellaneous	0	1	0	0	1
Total	1	3	13	10	27

Table 4.39.5. Large cutting tools broken down by its breakage pattern from Lakhmapur.

Large Cutting Tool Type	Breakage			Total
	Broken Tip	Broken buttend	Tip & Butt end broken	
Handaxe	5	2	0	7
Axe Blank	1	0	1	2
Total	**6**	**2**	**1**	**9**

Tip shape of large cutting tools

Table 4.39.6., provides tabulation for large cutting tool types and its tip shape. Out of 27 large cutting tools collected from the site of Lakhmapur, 21 had information on the tip shape. Out of 21 large cutting tools, 7 large cutting tools had markedly convergent tip shape (A type) next comes 9 markedly convergent with a generalized tip (D type), followed by 2 markedly convergent but with a squared off tip (B type), 2 markedly convergent with a generalized tip (D type) and 1 right angled and broad tip on an artifact with divergent or parallel/sub-parallel sides at the cutting end of the tool (E type). Table 4.39.6., reveals, information on tip shape and among 21 large cutting tools which had information on tip shape, 13 of them were axe blanks, in which 6 had 'D type' tip shape (i.e., markedly convergent with a generalized tip), 4 had 'A type' tip shape (i.e., markedly convergent tip), 2 had 'C type' (i.e., markedly convergent but with a squared off tip) and 1 had 'B type' (i.e., markedly convergent but with a squared off tip). All handaxes had markedly convergent tip shape (A type). All other tool types like cleaver, cleaver blank,

assayed core, discoid and other miscellaneous were minimum in count, from these cleaver (1) had markedly convergent with a generalized tip (D type), cleaver blank (1) had markedly convergent but with a squared off tip (B type), assayed core (1) had markedly convergent with a generalized tip (D type), discoid (1) had markedly convergent with a generalized tip (D type) and other miscellaneous (1) had right angled and broad tip on an artifact with divergent or parallel/sub-parallel sides at the cutting end of the tool (E type).

Table 4.39.6., indicates that majority of large cutting tools had markedly convergent with a generalized tip (D type) and markedly convergent tip shape (A type)

Table 4.39.6. Large cutting tools broken down by its tip shape from Lakhmapur.

Large Cutting Tool Type	Tip Shape					Total
	A type	B type	C type	D type	E type	
Handaxe	3	0	0	0	0	3
Cleaver	0	0	0	1	0	1
Axe Blank	4	1	2	6	0	13
Cleaver Blank	0	1	0	0	0	1
Assayed Core	0	0	0	1	0	1
Discoid	0	0	0	1	0	1
Other & Miscellaneous	0	0	0	0	1	1
Total	7	2	2	9	1	21

Cross Section of large cutting tool

Out of 27 large cutting tools, 25 gave cross section information from this site. From these 25, 17 large cutting tools have biconvex cross section, 5 have lenticular and 3 with high back cross section.

Out of these 25, 13 were axe blanks, 7 were handaxes remaining other types like cleaver, cleaver blank, assayed core, discoid and other miscellaneous were in least count (n=1). Axe blanks which are 13 in numbers, had 10 biconvex, 2 lenticular and 1 high back cross section. Then comes, 7 handaxe having 5 biconvex and remaining 2 had lenticular cross section. Cleavers and assayed core have 2 biconvex cross section whereas, cleaver blank and other miscellaneous have high back cross section and discoid from this site have lenticular cross section. **Thus**

Table 4.39.7. and Figure 4.39.1., indicates that majority of large cutting tool have biconvex cross section.

Table 4.39.7. Cross section for large cutting tools from Lakhmapur.

Large Cutting Tool Type	Cross Section			Total
	Biconvex	Lenticular	High Back	
Handaxe	5	2	0	7
Cleaver	1	0	0	1
Axe Blank	10	2	1	13
Cleaver Blank	0	0	1	1
Assayed Core	1	0	0	1
Discoid	0	1	0	1
Other & Miscellaneous	0	0	1	1
Total	17	5	3	25

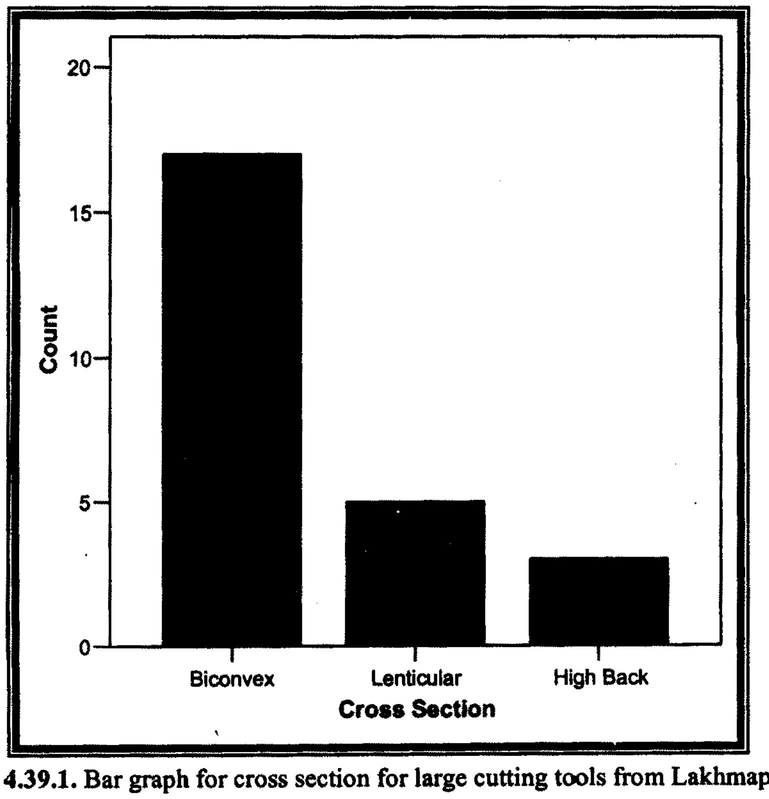

Figure 4.39.1. Bar graph for cross section for large cutting tools from Lakhmapur.

Profile Form for large cutting tools

All large cutting tools that were collected from the site Lakhmapur had information on profile form, out of this 27, 19 of them have irregular, 6 have regular and 2 has straight profile cross section.

Out of these 27 large cutting tools, 19 had irregular, 6 had regular and 2 had straight profile form. From 9 handaxe which were collected, 7 had irregular, 1 had regular and 1 had straight profile form. Axe blanks which are in maximum in count (13), had 10 irregular, 2 regular and 1 had straight profile form (Table 4.39.8). Other large cutting tool types like cleaver, cleaver blank, assayed core, discoid and other miscellaneous were least count (n=1), from these cleaver and other miscellaneous type had irregular profile form. Remaining types like cleaver blanks, assayed core and discoid had regular profile form. From this table it is clear that most of the large cutting tool types had irregular profile form (Figure 4.39.2).

Table 4.39.8. Profile form for large cutting tools from Lakhmapur.

Large Cutting Tool Type	Profile Form			Total
	Straight	Regular	Irregular	
Handaxe	1	1	7	9
Cleaver	0	0	1	1
Axe Blank	1	2	10	13
Cleaver Blank	0	1	0	1
Assayed Core	0	1	0	1
Discoid	0	1	0	1
Other & Miscellaneous	0	0	1	1
Total	**2**	**6**	**19**	**27**

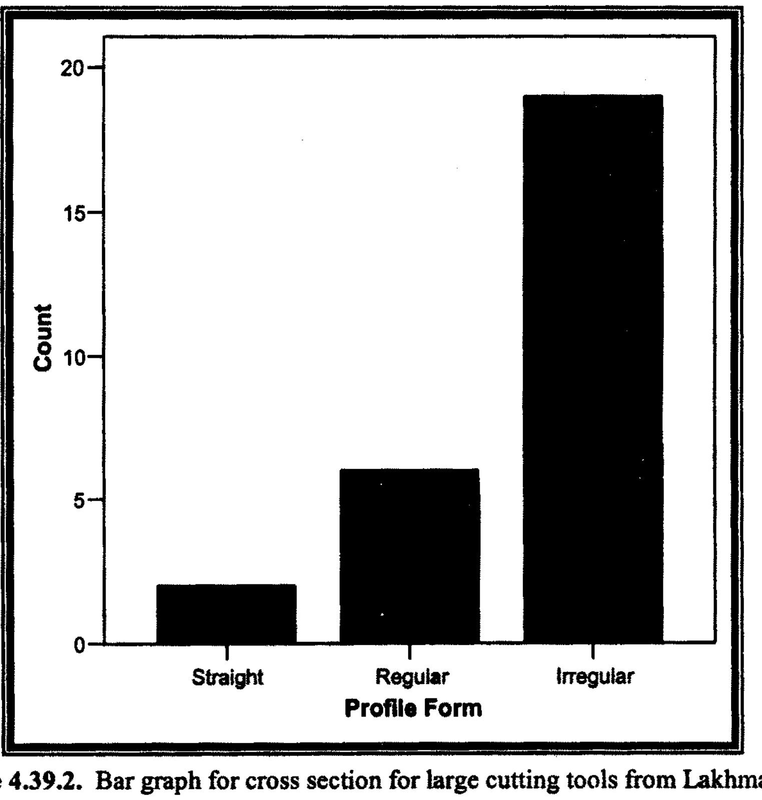

Figure 4.39.2. Bar graph for cross section for large cutting tools from Lakhmapur.

4.40. General metrical attributes recorded for large cutting tools

General attributes like maximum dimension, maximum width, thickness and weight were recorded in order to explain the size and shape of large cutting tools from Lakhampur. Mean, standard deviation and coefficient of variation values and simple plots (bar, line, histogram, box and scatter) were applied in order to explain the variability within large cutting tool's size and shape.

Table 4.40.1., provides a box plot of maximum dimension for all large cutting tools. Standard deviation and coefficient of variation indicates significant variability in large cutting tool types. But most of the large cutting tool types are in least count (n=1), so the results from this comparison should be taken cautiously. Large cutting tool weight varies considerably (CV=0.17) between large cutting tools. Heaviest large cutting tool types are assayed core (465 gms) and the lights large cutting tool types were cleaver (210 gms) and discoid (210 gms). Large cutting tool's maximum width is similar to thickness in variability (CV=0.07). The widest large cutting tool are cleaver blanks (91.28 mm) and the narrowest are cleaver (69.13 mm); while the thickest large cutting tool are assayed core (59.75 mm) and the thinnest are discoid (28.34 mm). Among all the 4 metrical attribute for large cutting tool types, maximum dimension is the least variable (CV=0.06). Longest large cutting tool are handaxe (126.21 mm) and shortest are discoid (90.04 mm).

Table 4.40.1. Mean, minimum, maximum, standard deviation and coefficient of variation of general metrical measurements for large cutting tool types from Lakhmapur.

Variable	Large Cutting Tool Type	Mean	Std. Deviation	CV
Maximum Dimension	Handaxe	126.21	23.03	0.18
	Axe Blank	120.25	24.99	**0.21**
	Cleaver	101.26	0	0
	Cleaver Blank	112.77	0	0
	Assayed Core	117.87	0	0
	Discoid	90.04	0	0
	Other & Miscellaneous	95.66	0	0
	Total	109.15	6.86	0.06
Maximum Width	Handaxe	83.21	20.03	**0.24**
	Axe Blank	86.99	19.02	0.22
	Cleaver	69.13	0	0
	Cleaver Blank	91.28	0	0
	Assayed Core	84.72	0	0
	Discoid	77.72	0	0
	Other & Miscellaneous	73	0	0
	Total	80.86	5.58	0.07
Thickness	Handaxe	40.93	7.20	0.18
	Axe Blank	41.74	12.34	**0.30**
	Cleaver	37.21	0	0
	Cleaver Blank	32.07	0	0
	Assayed Core	59.75	0	0
	Discoid	28.34	0	0
	Other & Miscellaneous	38.47	0	0
	Total	39.79	2.79	0.07
Weight	Handaxe	441.67	243.40	0.55
	Axe Blank	410.84	249.06	**0.61**
	Cleaver	210	0	0
	Cleaver Blank	355	0	0
	Assayed Core	465	0	0
	Discoid	210	0	0
	Other & Miscellaneous	285	0	0
	Total	339.64	70.35	0.17

Table 4.40.1., revealed that assayed core are the heaviest and thickest large cutting tool types, whereas, discoid are the lightest, thinnest and shortest. Cleaver blank is the widest while, cleaver is the narrowest large cutting tool types and handaxes are the longest large cutting tool type. Regarding the variability, axe blanks show grater variation in maximum dimension, thickness and weight, while, handaxe show variability in maximum width than all other large cutting tool types.

Correlation between general metrical measurements recorded for large cutting tools.

A bivariate correlation test was intended in order to find out the relationship within and between the general linear measurements, and the results are as following:

From Table 4.40.2., it is clear that maximum dimension, maximum width, thickness and weight of the large cutting tools have a significant correlation at 0.01 level (significantly different) and the positive Pearson Correlation indicates that, as the maximum dimension value increases, the value of other variables (maximum width, thickness and weight) also increases. When the thickness is compared with maximum width, the correlation was significant at 0.05 levels.

Table 4.40.2. Bivariate correlation test result within and between large cutting tools general linear attributes. All general linear attribute which are significant at 0.01 level are in blue colour and 0.05 in red colour. The attribute which are significant in 2-tailed level are marked in bold.

Correlations					
Variable	**Correlation Test**	**Maximum Dimension**	**Maximum Width**	**Thickness**	**Weight**
Maximum Dimension	Pearson Correlation	1	0.728	0.719	0.913
	Sig. (2-tailed)		0.000	0.000	0.000
	N	27	27	27	27
Maximum Width	Pearson Correlation	0.728	1	0.468	0.791
	Sig. (2-tailed)	0.000		0.014	0.000
	N	27	27	27	27
Thickness	Pearson Correlation	0.719	0.468	1	0.727
	Sig. (2-tailed)	0.000	0.014		0.000
	N	27	27	27	27
Weight	Pearson Correlation	0.913	0.791	0.727	1
	Sig. (2-tailed)	0.000	0.000	0.000	
	N	27	27	27	27

From the above table and from its description it can be summarized that the bivariate correlation test revealed interesting aspects of the large cutting tools and they are:

➢ Linear measurements for shape/morphology and size of large cutting tools like maximum dimension, maximum width, thickness and weight showed an increase in the value (Figure 4.40.1 to 4.40.3) when it was compared within the group itself along with the positive Pearson Correlation value. But when thickness is compared with the maximum width the Pearson Correlation value is in positive with the lowest value (0.468)

Figure 4.40.1 to 4.40.3., also shows that as the maximum dimension increases the maximum width, thickness and weight also increases. Maximum dimension versus maximum width has an isometric relationship within Lakhmapur large cutting tools (Figure 4.40.1). Figure 4.40.1., shows that when maximum dimension increases the maximum width also increases.

When maximum width is plotted against thickness, it also shows an isometric relationship within the large cutting tools (Figure 4.40.2) and this isometric relation shows that, as the maximum width increases thickness also increases.

When weight is plotted against maximum dimension, it also shows an isometric relationship within the large cutting tools (Figure 4.40.3) and this isometric relation shows that, as the weight increases with increase in maximum dimension.

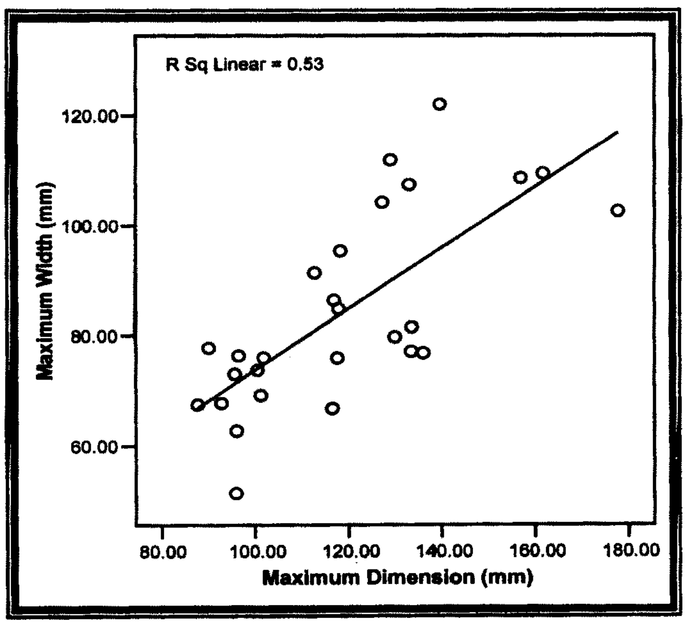

Figure 4.40.1. A scatter plot with simple linear regression line of maximum dimension versus maximum width for large cutting tools from Lakhmapur. The relationship between maximum dimension and maximum width is reasonably isometric.

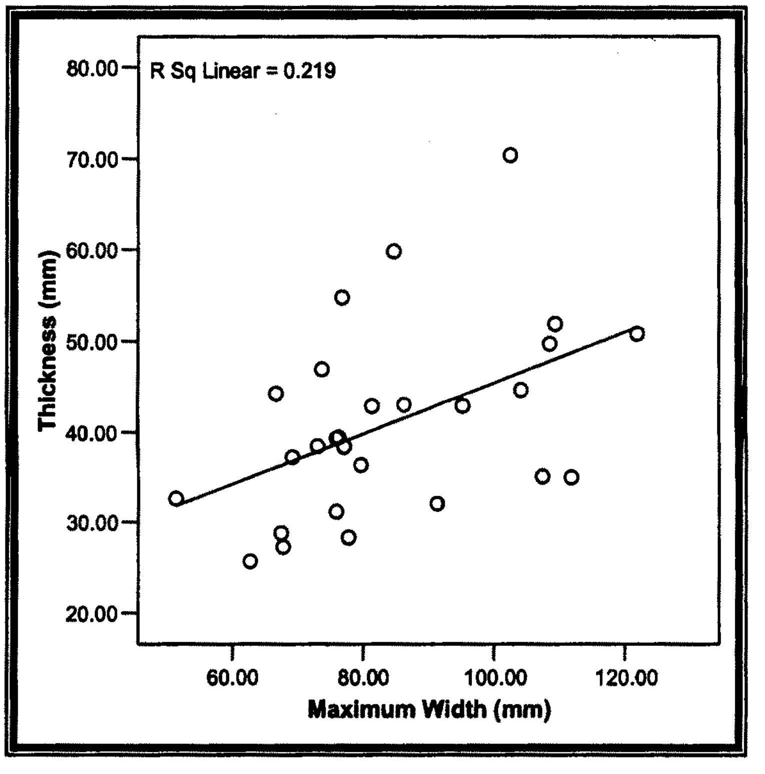

Figure 4.40.2. A scatter plot with simple linear regression line of maximum width versus thickness for large cutting tools from Lakhmapur. The relationship between maximum width and thickness is reasonably isometric.

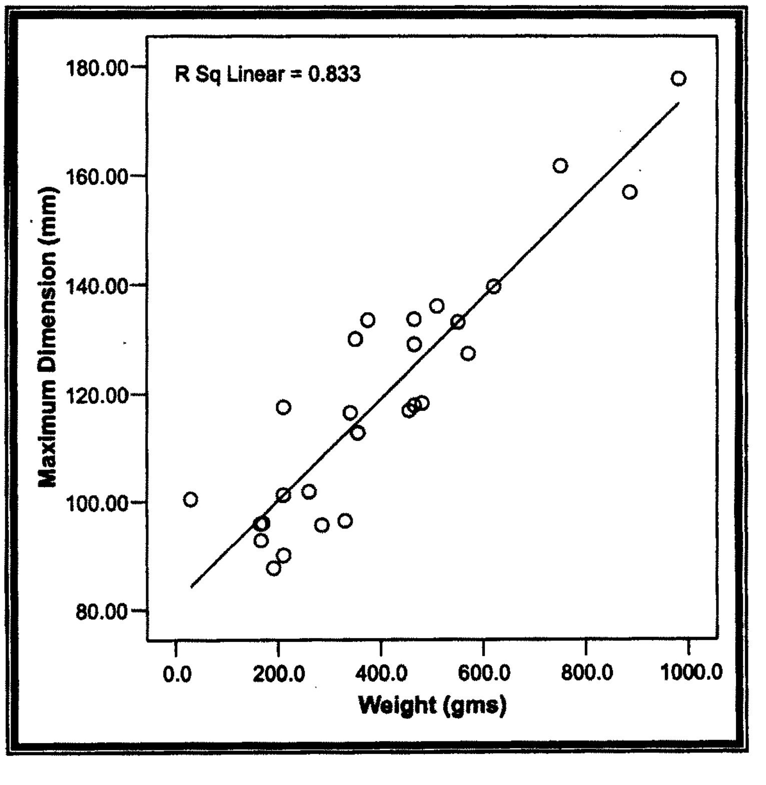

Figure 4.40.3. A scatter plot with simple linear regression line of weight versus maximum dimension for large cutting tools from Lakhmapur. The relationship weight and maximum dimension is reasonably isometric.

4.41. Additional metrical measurements for measuring size and shape of large cutting tool types

Additional measurements for shape/morphological measures of large cutting tools were also taken. Table 4.41.1., provides the mean, standard deviation and coefficient of variation of tip width (B1), mid width (B2), base width (B3), tip thickness (T1), mid thickness (T2), base thickness (T3), base length and tip length of the large cutting tools.

Table 4.41.1., provides the tabulation of morphological measurements of large cutting tool types. Table 4.41.1., reveals that broadest tip width for large cutting tools was of cleaver blank (75.24 mm) and narrowest was for handaxe (36.06±2.17mm). Regarding mid width of large cutting tool types show that cleaver blanks are wider (83.06 mm), but discoid have the narrowest mid width value (76.68 mm). Base of axe blanks are wider (75± 14.07mm), whereas, cleaver has the narrowest base width (34.15 mm).

Axe blanks had the thickest tip (18.52±5.19 mm) and cleaver has the thinnest tip (14.02 mm) among all large cutting tool types, whereas, assayed core has the thickest mid portion (46.59 mm) and cleaver blank has the thinnest mid thickness mean value (27.93 mm). Assayed core (53.11 mm) are thicker at the base and at the same time discoid are the thinnest (19.73 mm) at the base. Cleavers blank has the longest base length (53.11 mm), whereas, discoid has the smallest base length (18.3 mm). When tip length is taken into account, handaxe has the longest tip length (97.49±11.78 mm), whereas, cleaver blank has the shortest tip length (47.9 mm).

Table 4.41.1. Mean, minimum, maximum, standard deviation and coefficient of variation of additional metrical measurements for large cutting tool types from Lakhmapur.

Variable	Large Cutting Tool Type	Mean	Std. Deviation	CV
Tip Width (B1)	Handaxe	36.065	2.17	0.06
	Axe Blank	42.04	11.15	0.27
	Cleaver	45.75	0	0
	Cleaver Blank	75.24	0	0
	Assayed Core	42.89	0	0
	Discoid	53.53	0	0
	Total	49.25	2.22	0.05
Mid Width	Handaxe	68.86	2.72	0.04
	Axe Blank	79.877	16.55	0.21
	Cleaver	62.58	0	0
	Cleaver Blank	83.06	0	0
	Assayed Core	82.6	0	0
	Discoid	76.68	0	0
	Total	75.61	3.21	0.04
Base Width (B3	Handaxe	60.585	14.56	0.24
	Axe Blank	75	14.07	0.19
	Cleaver	34.15	0	0
	Cleaver Blank	60.99	0	0
	Assayed Core	70.25	0	0
	Discoid	51.49	0	0
	Total	58.75	4.77	0.07
Tip Thickness (Th1)	Handaxe	16.69	4.58	0.27
	Axe Blank	18.52	5.19	0.28
	Cleaver	14.02	0	0
	Cleaver Blank	18.27	0	0
	Assayed Core	20.3	0	0
	Discoid	14.28	0	0
	Total	17.01	1.63	0.09

Contd……

Mid Thickness (Th2)	Handaxe	36.805	2.23	0.06
	Axe Blank	41.002	9.95	0.24
	Cleaver	30.64	0	0
	Cleaver Blank	27.93	0	0
	Assayed Core	46.59	0	0
	Discoid	28.01	0	0
	Total	35.16	2.03	0.05
Base Thickness (Th3)	Handaxe	28.31	3.75	0.13
	Axe Blank	33.631	10.57	0.31
	Cleaver	21.28	0	0
	Cleaver Blank	37.38	0	0
	Assayed Core	53.11	0	0
	Discoid	19.73	0	0
	Total	32.24	2.39	0.07
Base Length	Handaxe	34.25	9.31	0.27
	Axe Blank	52.80	18.11	0.34
	Cleaver	41.28	0	0
	Cleaver Blank	64.79	0	0
	Assayed Core	50.14	0	0
	Discoid	18.3	0	0
	Total	43.59	4.57	0.10
Tip Length	Handaxe	97.49	11.78	0.12
	Axe Blank	68.511	21.99	0.32
	Cleaver	59.58	0	0
	Cleaver Blank	47.9	0	0
	Assayed Core	67.73	0	0
	Discoid	71.74	0	0
	Total	68.83	5.63	0.07

Therefore, from the above description and Table 4.41.1., it can be inferred that, handaxe are longer in tip with narrow tip. Cleaver blanks from this site have longer base length with shorter tip length and are wider at the tip and mid portion with thinnest mid portion, whereas, cleaver are narrowest at the base and thinnest at the tip. From this site axe blanks are wider at the base and are thicker at tip. Discoid are narrower at mid portion and are thinner at base with shortest base length. Assayed core at this site are thickest at the mid portion and at the base.

The general measurements like B1, B2, B3, T1, T2 and T3 were then generated to define the edge shape, elongation and refinement of large cutting tools. Table 4.41.2., provides the mean, standard deviation and coefficient of variation values for these index.

Large cutting tool type's index ratios (breadthl/ breadth3, length/breadth, and breadth/thickness) are quite variable among handaxes and axe blanks because other tool types are in minimum count. Elongation index ratio show that axe blanks (CV=0.15) are variable than handaxe types (CV=0.14). In refinement, handaxes (CV=0.30) show a great deal of variation than axe blanks (CV=0.29). When refinement is taken into account axe blanks (CV=0.25) show much variation that handaxes (CV=0.16). High mean values for elongation index ratio of handaxe (1.55±0.22) indicates that handaxes are more elongated than other tool types, whereas, discoid (1.16) are the shortest. High mean value for cleavers (1.34) in edge shape ratio indicates that cleavers are broader than other large cutting tool types, whereas, axe blanks are (0.57) are narrower than other tool types. When refinement is taken into account, discoid have a high mean value (2.74) at the same time assayed core (1.42) have the lowest mean value in refinement, indicative of thicker assayed core at this site.

Table 4.41.2. Mean, minimum, maximum, standard deviation and coefficient of variation of shape defining index ratios for large cutting tool types from Lakhmapur.

Index Ratio	Large Cutting Tool Type	Mean	Std. Deviation	CV
Elongation	Handaxe	1.55	0.22	0.14
	Axe Blank	1.40	0.21	0.15
	Cleaver	1.46	0	0
	Cleaver Blank	1.24	0	0
	Assayed Core	1.39	0	0
	Discoid	1.16	0	0
	Other & Miscellaneous	1.31	0	0
	Total	1.36	0.06	0.04
Edge Shape	Handaxe	0.62	0.18	0.30
	Axe Blank	0.57	0.17	0.29
	Cleaver	1.34	0	0
	Cleaver Blank	1.23	0	0
	Assayed Core	0.61	0	0
	Discoid	1.04	0	0
	Other & Miscellaneous	0	0	0
	Total	0.77	0.05	0.08
Refinement	Handaxe	2.03	0.32	0.16
	Axe Blank	2.19	0.56	0.25
	Cleaver	1.86	0	0
	Cleaver Blank	2.85	0	0
	Assayed Core	1.42	0	0
	Discoid	2.74	0	0
	Other & Miscellaneous	1.90	0	0
	Total	2.14	0.13	0.06

All these indicate that handaxes are more elongated and discoid are the shortest among all other tool types. When edge shape is taken into account, cleaver is broader and axe blanks are narrower than other large cutting tool types. Whereas, assayed core from this site are the thickest and discoid are the thinnest among all large cutting tool types.

4.42. Differentiating large cutting tools

A discriminant function analysis was conducted using all general and additional measurements for shape/morphological measures of large cutting tool types from Lakhmapur, in order to differentiate them within the large cutting tool types. Table 4.42.1, 4.42.2 & 4.42.3 and Figure 4.42.1., provides the information on three centroidal groups which were obtained during comparisons made among maximum dimension, maximum width, thickness, tip width, mid width, base width, tip thickness, mid thickness; base thickness, base length, tip length, tip shape, elongation index, edge shape index and refinement index of large cutting tool types and it is also clear from Table 4.42.1., which shows that three functions that were obtained from the canonical discriminant function analysis has different eigenvalues with three different percentage of variances, with 99.079 eigenvalue for the first function having 94.8% of variance; 3.642 eigenvalue with 3.5% variance for the second function and 1.744 eigenvalue with 1.7% variance for the third function and Wilk's Lambda for function 1 through 3 functions is .036 having significant value.

Table 4.42.1. Obtaining eigenvalues with the help of three functions for differentiating large cutting tool types from Lakhmapur.

Eigenvalues				
Function	**Eigenvalue**	**% of Variance**	**Cumulative %**	**Canonical Correlation**
1	99.079	94.8	94.844	0.995
2	3.642	3.5	98.330	0.886
3	1.744	1.7	100	0.797

A structure matrix correlation test was obtained with the help of these three functions of variables for large cutting tool types. This structure matrix which was obtained to show the correlation for each variables that were chosen for this analysis are shown in Table 4.42.2., also gives further information about the significant correlation in three functions like, the Function 1 is shown with significant result in base length, the Function 2 shows that edge shape, mid thickness, thickness and elongation are significantly different and Function 3 with significantly differ in base width, tip width, base thickness, maximum width, tip length, mid width, tip thickness, maximum dimension, weight and refinement.

Table 4.42.2. Discriminant function structure matrix of different variables for three functions, using large cutting tool types from Lakhmapur.

Structure Matrix			
Variable	**Function**		
	1	**2**	**3**
Base Length	0.158	-0.053	-0.097
Edge Shape	0.181	-0.552	-0.103
Mid Thick	-0.028	0.229	0.032
Thickness	-0.011	0.192	-0.035
Elongation	-0.096	-0.099	-0.060
Base Width	-0.020	0.387	0.419
Tip Width	0.088	-0.165	0.291
Base Thickness	0.011	0.120	0.270
Maximum Width	0.011	0.152	0.259
Tip Length	-0.208	0.102	0.242
Mid Width	0.014	0.152	0.217
Tip Thickness	0.001	0.106	0.156
Maximum Dimension	-0.030	0.040	0.154
Weight	-0.008	0.122	0.134
Refinement	0.097	-0.111	0.132

With the help of these three eigenvalues, three functions were obtained; when these three functions were compared within the variables of large cutting tool types which were selected for this analysis gave a significant result for obtaining group centroidal values (Table 4.42.3)., with positive and negative values. Table 4.42.3., clearly shows that large cutting tool types- handaxes fall in first group, axe blanks fall into the second group and cleaver and cleaver blank fall into the third group with centroidal values. Figure 4.42.1., also clearly shows that the three groups (the first group consists of handaxes, second group consist of axe blanks and the third group consisted of cleaver and cleaver blank) from Lakhmapur are significantly different from each other.

Table 4.42.3. Three functions of large cutting tool types for obtaining group centroidal values.

Functions at Group Centroids			
Large Cutting Tool Type	**Function**		
	1	**2**	**3**
Handaxe	-14.650	-2.723	0.382
Cleaver	9.918	-2.039	-3.532
Axe Blank	-0.213	1.015	0.061
Cleaver Blank	21.511	-2.668	2.154

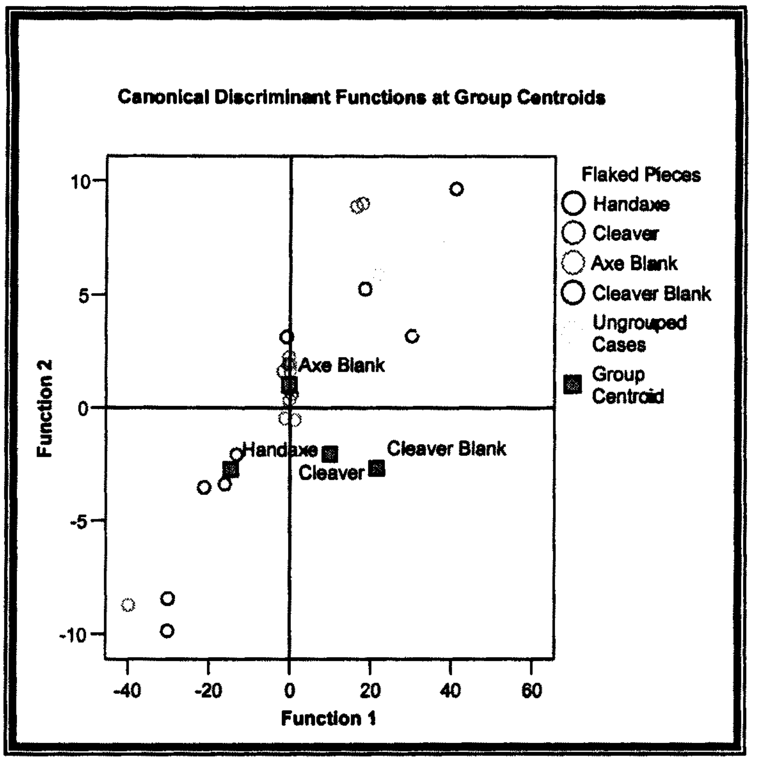

Figure 4.42.1. A scatter plot of discriminant functions 1 and 2 for large cutting tool types from Lakhmapur.

In supportive of the two centroidal groups which were obtained from structure matrix function, the Fisher's linear discriminant function (Table 4.42.4) is also applied in order to classify the function of coefficients for large cutting tool types with its size and shape measurements. Hence Table 4.42.4., clearly indicates that the large cutting tool types from Lakhmapur which shows high variation in maximum dimension, maximum width, thickness, weight, tip width (B1), mid width

(B2), base width (B3), tip thickness (T1), mid thickness (T2), base thickness (T3), base length, tip length, tip shape, elongation and edge shape and refinement.

Table 4.42.4. Fisher's linear discriminant function of variables for large cutting tool types from Lakhmapur.

Classification Function Coefficients				
Variable	**Large Cutting Tool Type**			
	Handaxe	**Cleaver**	**Axe Blank**	**Cleaver Blank**
Maximum Dimension	10.039	0.648	4.088	-3.457
Maximum Width	27.438	-4.308	8.255	-19.249
Thickness	-32.860	3.157	-12.733	18.056
Weight	-0.259	-0.226	-0.226	-0.191
Tip Width (B1)	-17.436	2.089	-5.885	12.072
Mid Width	-17.368	5.387	-3.356	14.601
Base Width (B3)	-4.006	-0.701	-1.802	1.754
Tip Thickness (Th1)	11.018	-2.129	3.034	-7.013
Mid Thick	19.988	1.563	10.979	-6.416
Base Thickness (Th3)	-7.836	0.186	-2.984	4.349

4.43. Accessing variability within large cutting tool types

Effects on variability between and within the large cutting tool type's will be explained with the help of raw material variability (i.e., types, size and shape) and stages of reduction in the upcoming analysis and comparison made between the natural clast type and flaked pieces were also taken up in the upcoming analysis.

Variability in raw material types to explain the variability in large cutting tool types.

At Lakhmapur, all large cutting were manufactured only on quartzarenites (quartzite) (96.3%), except 1 (3.7%) handaxe which was made on sandstone (Table 4.39.1). Due to the low count of different types of raw material used from this site, no statistical analysis could be done. For this reason, raw material type could not explain the variability in morphology of large cutting tool types.

In order to test the effect of shape and size of raw material on the variability observed in the morphology of large cutting tool types, initial form and cortex type of large cutting tools were compared with general and additional measurements.

Influence of initial form on the variability observed in the large cutting tool types

Out of 27 large cutting tools, 13 were axe blanks, 9 were handaxe and other tool types which are least in count (n=1) like cleaver, cleaver blank, assayed core, discoid and other miscellaneous. As said in the previous section of this chapter (Table 4.39.4), majority of the large cutting tools were made from flakes (13), others on indeterminate (10), slabs (11), and blocky (4).

Table 4.43.1., is a comparison made between and within the large cutting tool types with its initial form. Variability observed within large cutting tool types are explained, when comparison is made between large cutting tool types with its initial form, handaxes made on slabs had the highest mean value in maximum dimension (161.72 mm), maximum width (109.39 mm) and in weight (750 gms), while, assayed core made from blocky clast type have the highest mean value in thickness (59.75 mm). Discoid from this site have the lowest mean value in maximum dimension (90.04 mm) and thickness (28.34 mm), and when maximum width is considered cleaver has the lowest mean value (69.13 mm). At the same time, weight of discoid and cleaver are same (210 gms).

Large cutting tool types like cleaver, cleaver blank, assayed core, discoid and other & miscellaneous are in least count (n=1), so no comparison could be made within them by its initial form. As handaxes (9) and axe blanks (13) are more in count, a comparison could be made within them by its initial forms. As observed earlier (see Table 4.39.4), handaxes are made from three types of initial forms and they are slab, flake and indeterminate, and when this type (handaxe) are compared between the initial forms, handaxes made from slab have higher mean value in maximum dimension (161.72 mm), maximum width (109.39 mm), thickness (51.83 mm) and weight (750 gms), at the same time, handaxe made from indeterminate have the lowest mean value in maximum dimension (116.62 mm), maximum width (75.86 mm), thickness (39.28 mm) and weight (355 gms). When axe blanks are compared within its initial form, axe blanks made from flakes have higher mean value in maximum dimension (121.59 mm) and in thickness (43.90 mm), while, axe blanks made from slabs have higher mean value in maximum width (95.25 mm) and weight (480 gms). At the same time, when axe blanks are made from indeterminate, they show, lowest mean value in maximum dimension (114.56 mm), in maximum width (85.04 mm), in thickness (30.38 mm) and in weight (359.95 gms).

Table 4.43.1. Mean, standard deviation and coefficient of variation for general metrical measurements of large cutting tool types broken down by its initial form from Lakhmapur.

Large Cutting Tool Type	Initial Form	Variable	Mean	Std. Deviation	CV
Handaxe	Slab	Maximum Dimension	161.72	0	0
		Maximum Width	109.39	0	0
		Thickness	51.83	0	0
		Weight	750	0	0
	Flake	Maximum Dimension	137.25	27.81	0.20
		Maximum Width	92.20	23.13	0.25
		Thickness	40.42	13.10	0.32
		Weight	547.5	477.30	0.87
	Indeterminate	Maximum Dimension	116.62	16.81	0.14
		Maximum Width	75.86	17.34	0.23
		Thickness	39.28	4.63	0.12
		Weight	355	129.31	0.36
Cleaver	Indeterminate	Maximum Dimension	101.26	0	0
		Maximum Width	69.13	0	0
		Thickness	37.21	0	0
		Weight	210	0	0
Axe Blank	Flake	Maximum Dimension	121.59	27.33	0.22
		Maximum Width	86.55	19.04	0.22
		Thickness	43.90	12.81	0.29
		Weight	414.1	271.22	0.65
	Slab	Maximum Dimension	118.28	0	0
		Maximum Width	95.25	0	0
		Thickness	42.88	0	0
		Weight	480	0	0
	Indeterminate	Maximum Dimension	114.56	26.14	0.23
		Maximum Width	85.04	31.61	0.37
		Thickness	30.38	6.65	0.22
		Weight	359.95	268.77	0.75
Cleaver Blank	Flake	Maximum Dimension	112.77	0	0
		Maximum Width	91.28	0	0
		Thickness	32.07	0	0
		Weight	355	0	0

Contd......

Assayed Core	**Blocky**	Maximum Dimension	117.87	0	0
		Maximum Width	84.72	0	0
		Thickness	59.75	0	0
		Weight	465	0	0
Discoid	**Indeterminate**	Maximum Dimension	90.04	0	0
		Maximum Width	77.72	0	0
		Thickness	28.34	0	0
		Weight	210	0	0
Other & Miscellaneous	**Slab**	Maximum Dimension	95.66	0	0
		Maximum Width	73	0	0
		Thickness	38.47	0	0
		Weight	285	0	0

Therefore, Table 4.43.1 and Figure 4.43.1 to 4.43.4., indicated that handaxe made from slabs are the longest, widest, thickest and heaviest than handaxes made from other types of initial form (Figure 4.43.1 to 4.43.4), at the same time, handaxe made on indeterminate, were the shortest, narrowest, thinnest and lightest than handaxes made from other initial forms (Figure 4.43.1 to 4.43.4). When axe blanks are compared within its initial form, axe blanks made from flakes are longer and thicker, whereas, axe blanks made from slabs are wider and heavier (Figure 4.43.1 to 4.43.4). At the same time, the axe blanks which has indeterminate as the initial form they are shorter, narrower, thinner and lighter (Figure 4.43.1 to 4.43.4).

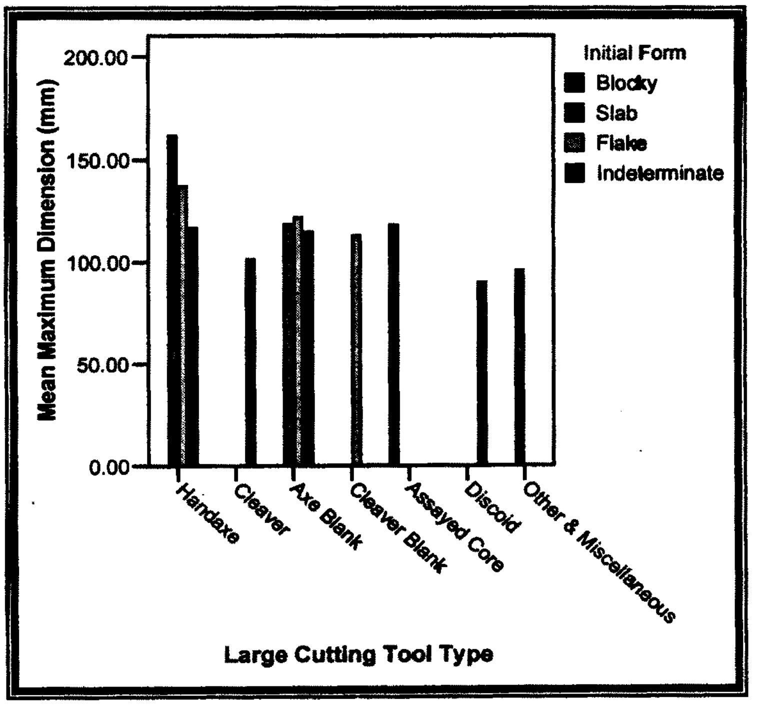

Figure 4.43.1. Bar graph of maximum dimension for large cutting tool types by its initial form from Lakhmapur.

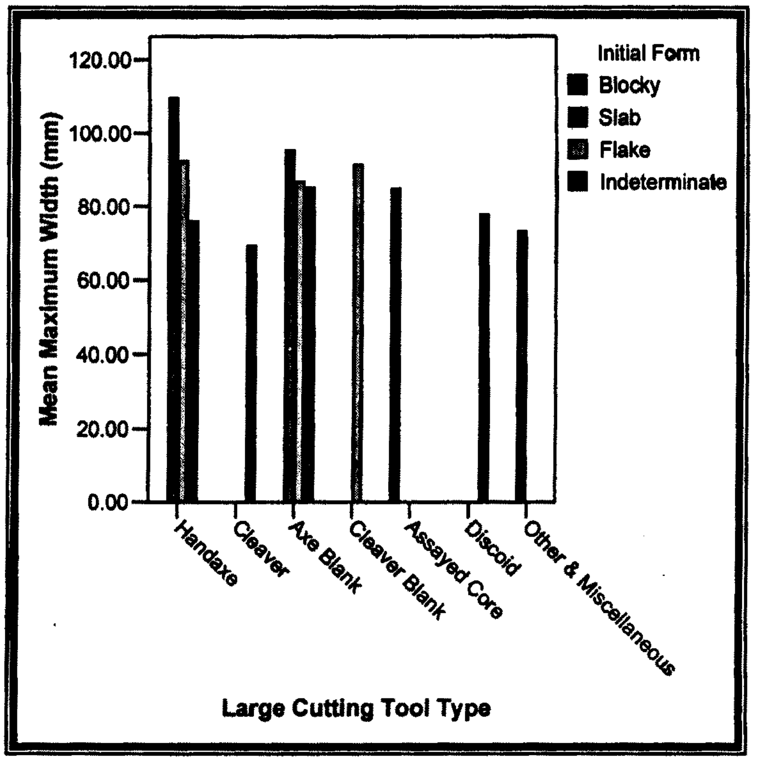

Figure 4.43.2. Bar graph of maximum width for large cutting tool types by its initial form from Lakhmapur.

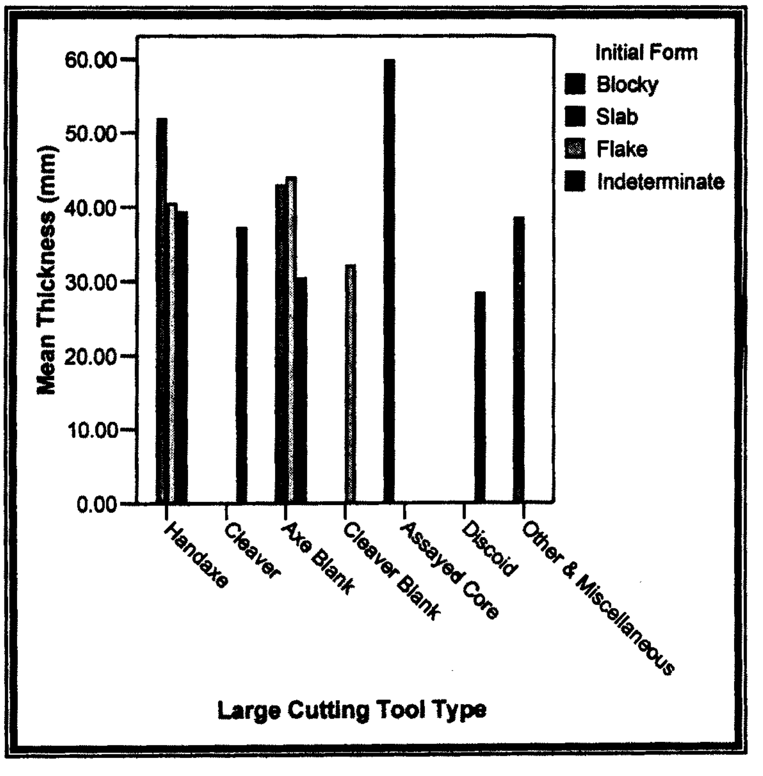

Figure 4. 43. 3. Bar graph of thickness for large cutting tool types by its initial form from Lakhmapur.

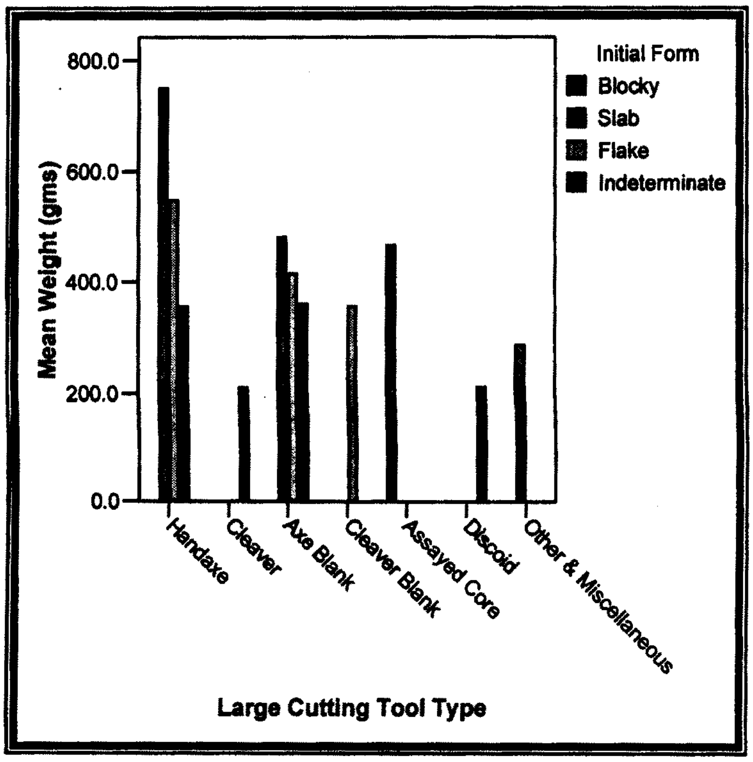

Figure 4.43.4. Bar graph of weight for large cutting tool types by its initial form from Shankaragatta.

Majority of large cuttings tools which has information on the initial forms are broken and they lack edge shape index ratio, the ones which have information on edge shape index ratio are shown in Table 4.43.2.

Table 4.43.2., shows the variability observed within the large cutting tool types is explained, when comparison is made between large cutting tool types by its initial forms, only 1 type of initial form were noticed on the following complete large cutting tools, and they are handaxes, cleaver, cleaver blank, assayed core, discoid and other miscellaneous, whereas, axe blanks which have information on the edge shape index ratio were made from three types of initial forms and they are flake, slab and indeterminate.

When comparison is made between large cutting tool types with its initial form, handaxe made on indeterminate are elongate (1.68) and cleaver made on the same type of initial form are broader (1.34), at the same time, axe blanks made on the same type of initial form (i.e., indeterminate) are thinnest (3.06). Whereas, discoid are the shortest (1.16) and axe blanks are the broadest (0.56) types, at the same time assayed core are the thickest (1.42).

When axe blanks are compared within its initial form, axe blanks made from flakes are longer (1.43) and broader (0.56) than axe blanks made from other types of initial forms. At the same time axe blanks made on indeterminate are thinnest among the axe blanks made from other initial forms.

Therefore, Table 4.43.2., indicated that large cutting tool types which has indeterminate as initial form are elongated, broader and thinner i.e., when handaxes were made from indeterminate are elongated, cleaver made from indeterminate are broader and axe blanks made from indeterminate are thinner.

Table 4.43.2. Mean, standard deviation and coefficient of variation for shape defining index ratio of large cutting tool types broken down by its initial form from Lakhmapur.

Large Cutting Tool Type	Initial Form	Index Ratio	Mean	Std. Deviation	CV
Handaxe	Indeterminate	Elongation	1.68	0.07	0.04
		Edge Shape	0.62	0.18	0.30
		Refinement	2.10	0.13	0.06
Cleaver	Indeterminate	Elongation	1.46	0	0.00
		Edge Shape	1.34	0	0.00
		Refinement	1.86	0	0.00
Axe Blank	Flake	Elongation	1.43	0.23	0.16
		Edge Shape	0.56	0.19	0.33
		Refinement	2.04	0.58	0.28
	Slab	Elongation	1.24	0	0.00
		Edge Shape	0.66	0	0.00
		Refinement	2.22	0	0.00
	Indeterminate	Elongation	1.24	0	0.00
		Edge Shape	0.59	0	0.00
		Refinement	3.06	0	0.00
Cleaver Blank	Flake	Elongation	1.24	0	0.00
		Edge Shape	1.23	0	0.00
		Refinement	2.85	0	0.00
Assayed Core	Blocky	Elongation	1.39	0	0.00
		Edge Shape	0.61	0	0.00
		Refinement	1.42	0	0.00
Discoid	Indeterminate	Elongation	1.16	0	0.00
		Edge Shape	1.04	0	0.00
		Refinement	2.74	0	0.00
Other & Miscellaneous	Slab	Elongation	1.31	0	0.00
		Edge Shape	0	0	0.00
		Refinement	1.90	0	0.00

Influence of cortex type on the variability observed in the large cutting tool types

Cortex type was also recorded in order to test the effect of shape and size of raw material on the variability in morphology of large cutting tools and preference of clast type by the hominins at this site. As said in the previous section of this chapter (Table 4.39.3), majority of the large cutting tools had the information on the cortex type was of angular clast type (10), and was followed 2 indeterminate type, 1 sub-angular and 1 sub-rounded.

Table 4.43.3., is a comparison made between and within the large cutting tool types with its cortex types. Variability observed within large cutting tool types are explained, when comparison is made between large cutting tool types with its cortex types, axe blanks which has little information (indeterminate) and which could not be clubbed into any cortex type have the highest mean in maximum dimension (177.73 mm), in maximum width (102.53 mm), in thickness (70.32 mm) and in weight (980 gms), indicative of axe blank type as the biggest among other large cutting tool types. Whereas, other miscellaneous which, has cortex information as angular type have the lowest mean value in maximum dimension (95.66 mm), thickness (38.47 mm) and weight (285 gms), and when maximum width is taken into account, handaxe which has the cortex information as indeterminate has the lowest mean value in maximum width (66.72 mm).

When handaxes are compared within its cortex type, handaxes made from angular cortex types have higher mean value in maximum dimension (138.18 mm), maximum width (89.74 mm), thicker (44.71 mm) and heavier (600 gms) than handaxe made from indeterminate. When axe blanks are compared between the cortex type, axe blanks made on indeterminate cortex types have highest mean value in maximum dimension (177.73 mm), in maximum width (102.53 mm), in thickness (70.32 mm) and in weight (980 gms). Other large cutting tool types had only one type of cortex information, this made it impossible to compare within them.

Table 4.43.3. Mean, standard deviation and coefficient of variation for general metrical measurements of large cutting tool types broken down by its cortex types from Lakhmapur.

Large Cutting Tool Type	Cortex Type	Variable	Mean	Std. Deviation	CV
Handaxe	Angular	Maximum Dimension	138.18	36.69	0.27
		Maximum Width	89.74	33.30	0.37
		Thickness	44.71	10.53	0.24
		Weight	600	382.72	0.64
	Indeterminate	Maximum Dimension	116.53	0	0
		Maximum Width	66.72	0	0
		Thickness	44.28	0	0
		Weight	340	0	0
Axe Blank	Angular	Maximum Dimension	113.60	20.42	0.18
		Maximum Width	85.94	19.97	0.23
		Thickness	41.93	7.53	0.18
		Weight	340.80	218.63	0.64
	Indeterminate	Maximum Dimension	177.73	0	0
		Maximum Width	102.53	0	0
		Thickness	70.32	0	0
		Weight	980	0	0
	Sub-Rounded	Maximum Dimension	116.91	0	0
		Maximum Width	86.3	0	0
		Thickness	43.03	0	0
		Weight	455	0	0
Assayed Core	Sub-Angular	Maximum Dimension	117.87	0	0
		Maximum Width	84.72	0	0
		Thickness	59.75	0	0
		Weight	465	0	0
Other & Miscellaneous	Angular	Maximum Dimension	95.66	0	0
		Maximum Width	73	0	0
		Thickness	38.47	0	0
		Weight	285	0	0

Hence, Table 4.43.3., indicated that axe blanks which had little information and was clubbed into the indeterminate category were the longest, widest, thickest and heaviest than other large cutting tool types, whereas, other miscellaneous which, had cortex information as angular type was the shortest, narrowest, thinnest and lightest.

When handaxe were compared with its cortex type, handaxe made from angular clast are longer, wider, thicker and heavier than handaxes which had indeterminate as the cortex type. When axe blanks are compared within its cortex type, axe blanks which had indeterminate as cortex type was the longest, widest, thickest and heaviest than, axe blanks made from angular or sub-rounded clast types.

Large cuttings tools which has information on the cortex types are broken and they lack edge shape cortex type, the ones which have information on edge shape index ratio are shown in Table 4.43.4.

Comparison made between large cutting tool types by its cortex type is another way of explaining the variability observed within the large cutting tool types. From Lakhmapur out of 9 complete large cutting tools, only three types (namely axe blank, assayed core and other miscellaneous) had information on the cortex type. Out of these three one type which had maximum amount of information on cortex type and that was axe blanks (7); other large cutting tool types which had information was of assayed core (1) and other miscellaneous (1).

Table 4.43.4., shows that, when comparison is made between large cutting tool types with its cortex types, axe blanks made on indeterminate are elongate (1.73) and the same tool type when it is made on sub-rounded clast type they have high refinement value (2.01), at the same time, when assayed core are made from sub-angular clast type, they have high edge shape value (0.61). Whereas, other miscellaneous made on angular cortex type are the shortest (1.31) and axe blanks made on indeterminate are the broadest (0.44) types, at the same time assayed core made from sub-angular are the thickest (1.42).

When axe blanks are compared within its cortex type, axe blanks made from indeterminate are longer (1.73) and axe blanks made from angular are broader (0.51), while axe blanks made from sub-rounded clast types are more refined (2.01)than axe blanks made from other types of initial forms. At the same time axe blanks made on angular and sub-rounded clast types have the same value (1.35), indicative of shorter axe blanks, and axe blanks made from indeterminate are broader (0.44) and thicker (1.46) among the axe blanks made from other initial forms. Other large cutting tools like assayed core and other miscellaneous could not be compared due to the low count in the tool types.

Therefore, Table 4.43.4., indicated that assayed core made on sub-angular clast types are the narrowest and thickest than all other large cutting tool types. Whereas, axe blanks made on indeterminate are elongated, broader and thinnest than other large cutting tool types.

Table 4.43.4. Mean, standard deviation and coefficient of variation for shape defining measurements of large cutting tool types broken down by its cortex types from Lakhmapur.

Large Cutting Tool Type	Cortex Type	Index Ratio	Mean	Std. Deviation	CV
Axe Blank	Angular	Elongation	1.35	0.19	0.14
		Edge Shape	0.51	0.10	0.20
		Refinement	2.00	0.32	0.16
	Indeterminate	Elongation	1.73	0	0
		Edge Shape	0.44	0	0
		Refinement	1.46	0	0
	Sub-Rounded	Elongation	1.35	0	0
		Edge Shape	0.50	0	0
		Refinement	2.01	0	0
Assayed Core	Sub-Angular	Elongation	1.39	0	0
		Edge Shape	0.61	0	0
		Refinement	1.42	0	0
Other & Miscellaneous	Angular	Elongation	1.31	0	0
		Edge Shape	0	0	0
		Refinement	1.90	0	0

Influence of reduction sequence on the variability observed in the large cutting tool types

In order to explain the variability between and within large cutting tool types and for explaining the reduction stages at Lakhmapur site, McPherron reduction model, total flake scar count, total number of non-feather termination and index of invasiveness were compared with elongation, edge shape and refinement ratio of large cutting tools. For this reason scatter plot with linear regression lines and box plots were used to give meaningful answers.

This variability in the large cutting tool types has been explained with the help of McPherron's, way, as suggested by McPherron tip length will be a primary measure of reduction intensity.

When large cutting tool's elongation ratio was compared with refinement ratio, it gave a significant correlation with positive Pearson Correlation value while using bivariate correlation test and other variables with tip length did not give any significant relations. Scatter plot with linear regression line explained the

relationship of elongation ratio, edge shape ratio and refinement ratio with tip length.

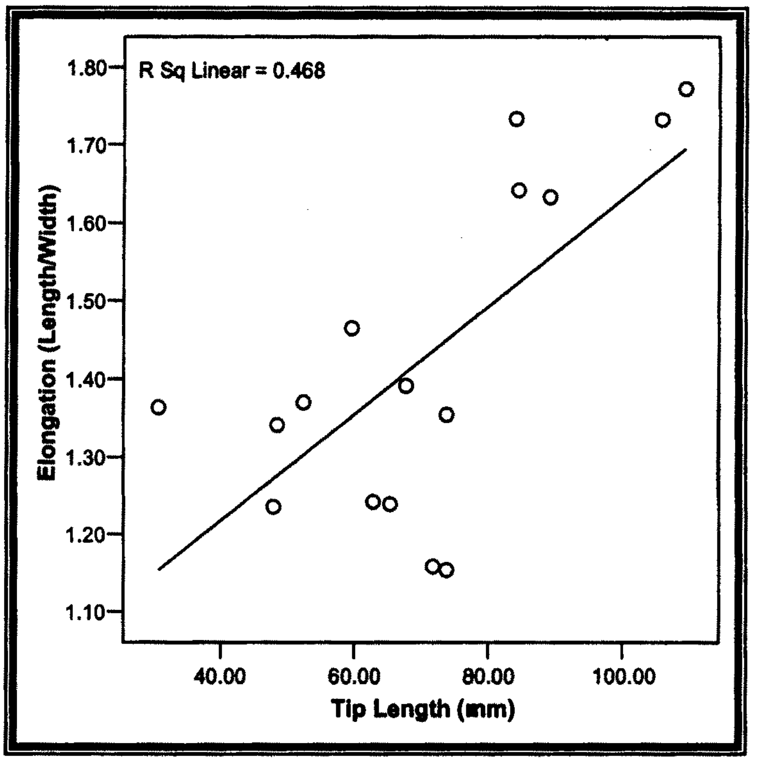

Figure 4.43.5. A scatter plot with simple linear regression of tip length versus elongation index ratio (length/width) for large cutting tools from Lakhmapur.

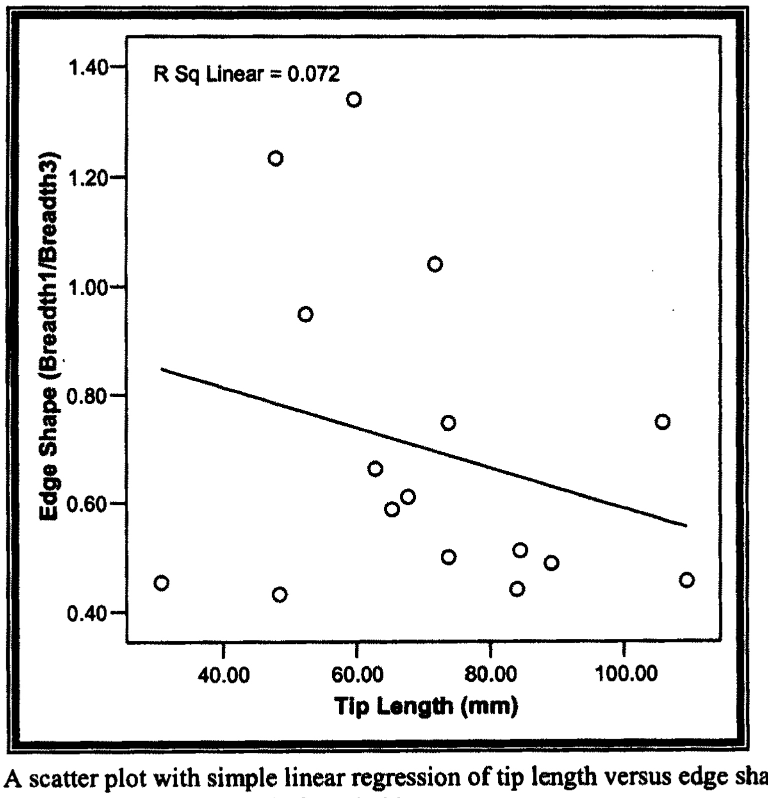

Figure 4.43.6. A scatter plot with simple linear regression of tip length versus edge shape index ratio (breadth1/breadth3) for large cutting tools from Lakhmapur.

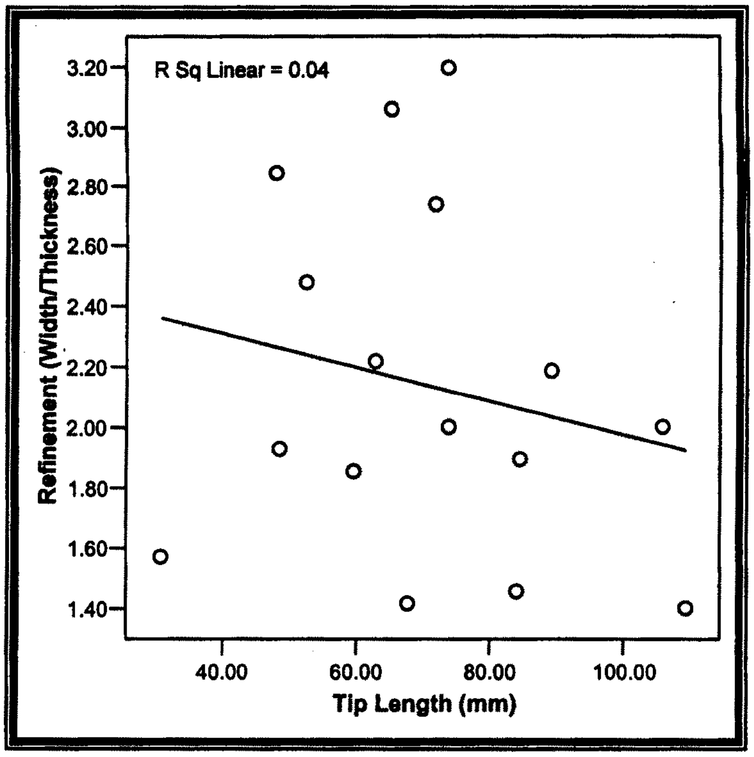

Figure 4.43.7. A scatter plot with simple linear regression of tip length versus refinement index ratio (width/thickness) for large cutting tools from Lakhmapur.

Figure 4.43.5., reveals that as the tip length increases gradually, the large cutting tools become more elongated. Whereas, in edge shape ratio, the relationship moves in different directions and it shows that as the tip length decreases, tools become broader (Figure 4.43.6). When refinement is taken into account, it raveled that, as the tip length increases the refinement ratio decreases, indicating thicker large cutting tools have longer tip length and thinner large cutting tool have shorter tip length (Figure 4.43.7).

All these indicate that as the reduction increases with the increase in tip length, large cutting tools become more elongated, broader and thicker and this in turn indicates that the large cutting tools from Lakhmapur are in early or middle stage of reduction.

When total flake scar, index of invasiveness and total number of non-feather termination are compared, by using bivariate correlation test, resulted in a significant correlation at 0.01 level and 0.05 level. Table 4.43.5., clearly shows that the total flake scar count of large cutting tools from Lakhmapur are significantly different with significant correlation at 0.01 level and the positive Pearson Correlation for the same also indicates that, as total flake scar count increases, the total number of non-

feather termination and index of invasiveness also increases. When total number of non-feather termination is compared with total flake scar count and index of invasiveness, it gave a significant value at 0.05 level and when the index of invasiveness is compared with total flake scar count and total number of non-feather termination, then it also gave a significant value at 0.05 level.

Table 4.43.5. Bivariate correlation test result between and within variables of large cutting tool types. All variables which are significant at 0.01 level are marked in bold and the general non-metrical variable which resulted in 0.05 level are marked in red colour.

Correlations				
Variable	**Correlation Test**	**Total Flake Scar Count**	**Total No. of Non-Feather Termination**	**Index of Invasiveness**
Total Flake Scar Count	Pearson Correlation	1	0.799	0.543
	Sig. (2-tailed)		0.000	0.036
	N	15	15	15
Total No. of Non-Feather Termination	Pearson Correlation	0.799	1	0.604
	Sig. (2-tailed)	0.000		0.008
	N	15	18	18
Index of Invasiveness	Pearson Correlation	0.543	0.604	1
	Sig. (2-tailed)	0.036	0.008	
	N	15	18	24

Total flake scar count

As stone knapping is a reductive or subtractive 'multi-staged' reductive process one, the stone undergoes sequential stages of reduction as core mass modified by the knapper. When the reduction advances, the count of flake removal increases and this could be notice on the flaked piece. Figure 4.43.8., shows the handaxes have higher mean value for total flake scar count than any other large cutting tool types. Whereas, though axe blanks have low mean flake scar count, they show much variation within them with higher spread in the inter-quartile range and its spread.

Figures 4.43.9 to 4.43.11., shows the changes in size and shape of large cutting tool types with the increase in stages of reduction. When elongation ratio is compared with total scar count, it resulted in the decrease in elongation index ratio with the increase in total scar count i.e., longer large cutting tools have few flakes scar count and shorter large cutting tools have more number of flake scar count (see,

Figure 4.43.9). At the same time when comparison was made with edge shape ratio by total scar count, it resulted in the increase in edge shape ratio with increase in total scar count, i.e., the broader large cutting tools have less number of flake scar count and narrower large cutting tools have higher flake scar count (see, Figure 4.43.10) and when refinement is considered it also gave the same result as what was seen in the previous one, like, when both refinement and total scar count are compared, it resulted in the increase in refinement with increase in total scar count, i.e., thicker large cutting tools with less number of flake scar count and thinner large cutting tools with more flake scar count (see, Figure 4.43.11).

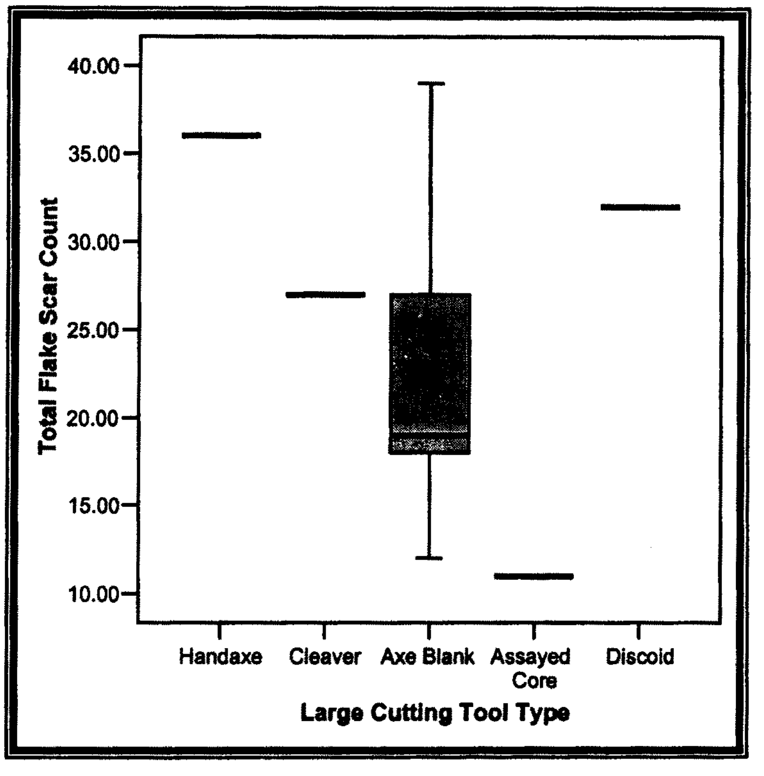

Figure 4.43.8. Box plot for total flake scar count of large cutting tool types from Lakhmapur.

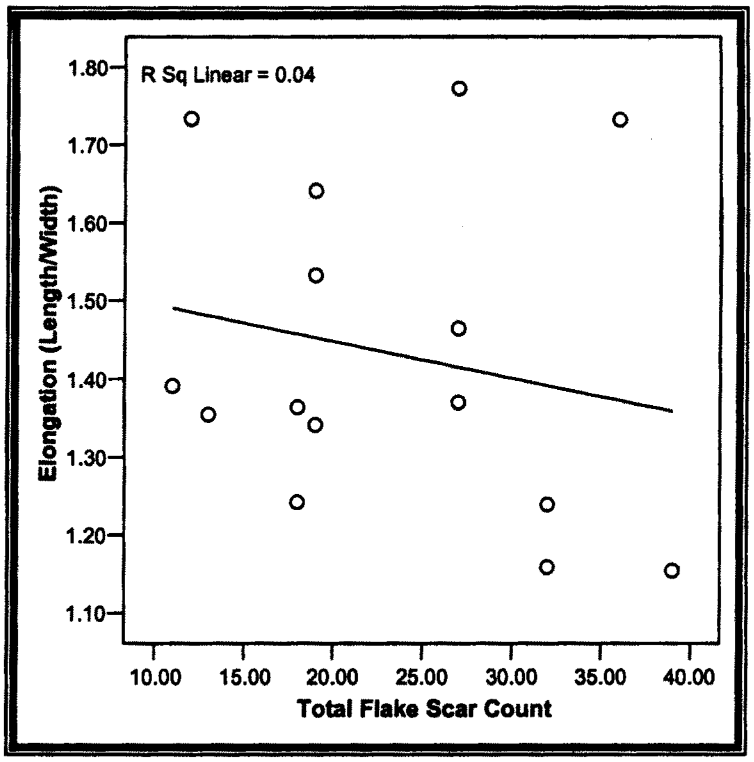

Figure 4.43. 9. A scatter plot of total flake versus elongation index ratio (length/width) for large cutting tool types from Lakhmapur.

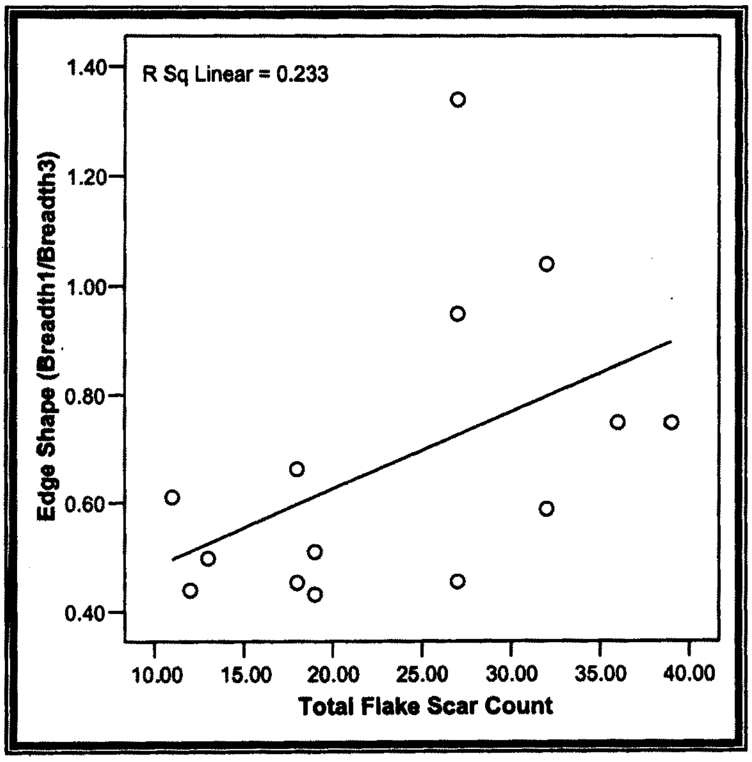

Figure 4.43.10. A scatter plot of total flake scar count versus edge shape index ratio (breadth1/breadth3) for large cutting tool types from Lakhmapur.

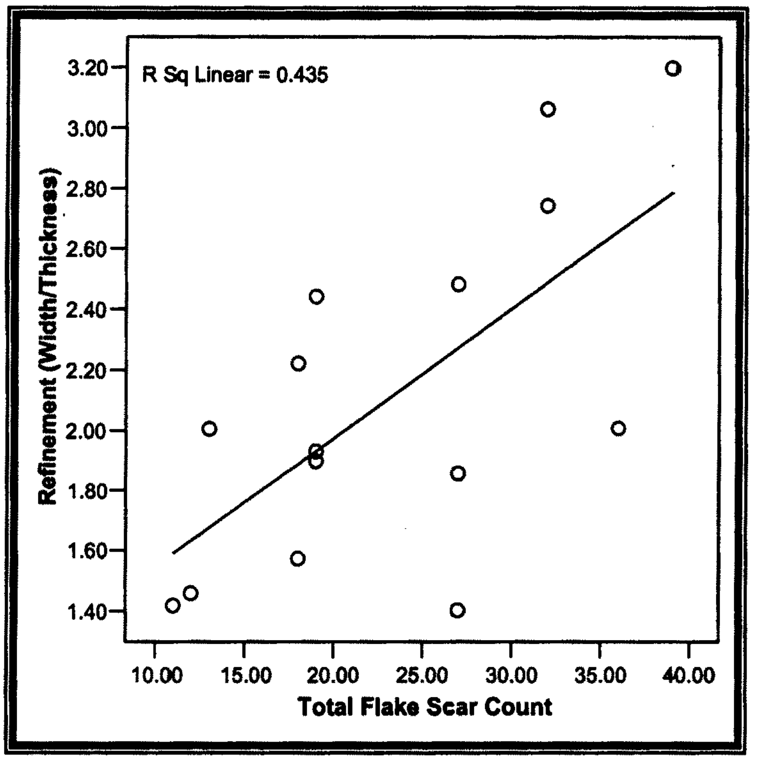

Figure 4.43.11. A scatter plot of total flake scar count versus refinement index ratio (width/thickness) for large cutting tool types from Lakhmapur.

Hence, all these indicates that as the reduction increases with the increase in flake scar count, large cutting tools become more elongated, broader and thicker, and this indicates that large cutting tools from Lakhmapur are in early or middle stage of reduction.

Index of invasiveness.

Index of invasiveness is also a measure to find the variability and reduction process in large cutting tool types; in which as the reduction advances the index of invasiveness also increases. Variability in shape within the large cutting tools is shown here with the comparison of elongation, edge shape and refinement index ratio by the index of invasiveness (see, Figure 4.43.12 to 4.43.15).

Figure 4.43.12., is a scatter plot for the comparison of elongation ratio with index of invasiveness. From this scatter plot it is clear that as the elongation index ratio decreases the value for index of invasiveness increases i.e., shorter large cutting tools have higher index of invasiveness, and longer large cutting tools have lower index of invasiveness. At the same time when index of invasiveness is compared with edge shape ratio, the shape ratio increases with the increase in index of invasiveness, i.e., narrower large cutting tools have higher index of invasiveness

value and broader large cutting tools have lower index of invasiveness (Figure 4.43.13) and when refinement is compared with index of invasiveness, it also revealed that, as refinement ratio increases, index of invasiveness also increases i.e., thinner large cutting tools have higher value of index of invasiveness and thicker large cutting tools have lower index of invasiveness value (Figure 4.43.14).

Hence, all these indicate that as the reduction increases with the increase in the index of invasiveness, large cutting tools become shorter, narrower and thinner and this indicates that large cutting tools from Lakhmapur were in the early or middle stage of reduction.

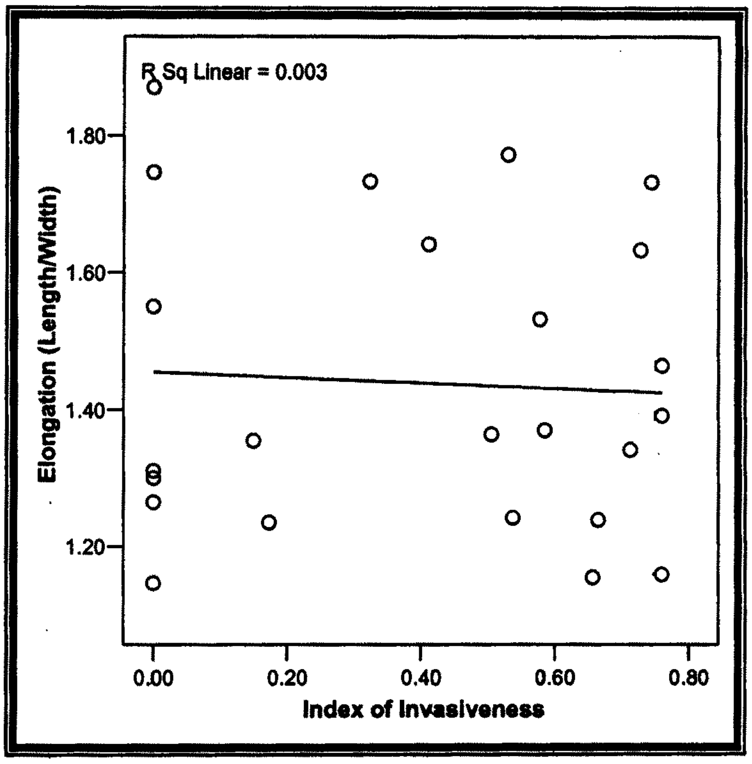

Figure 4.43.12. A scatter plot of index of invasiveness versus elongation index ratio (length/width) for large cutting tool types from Lakhmapur.

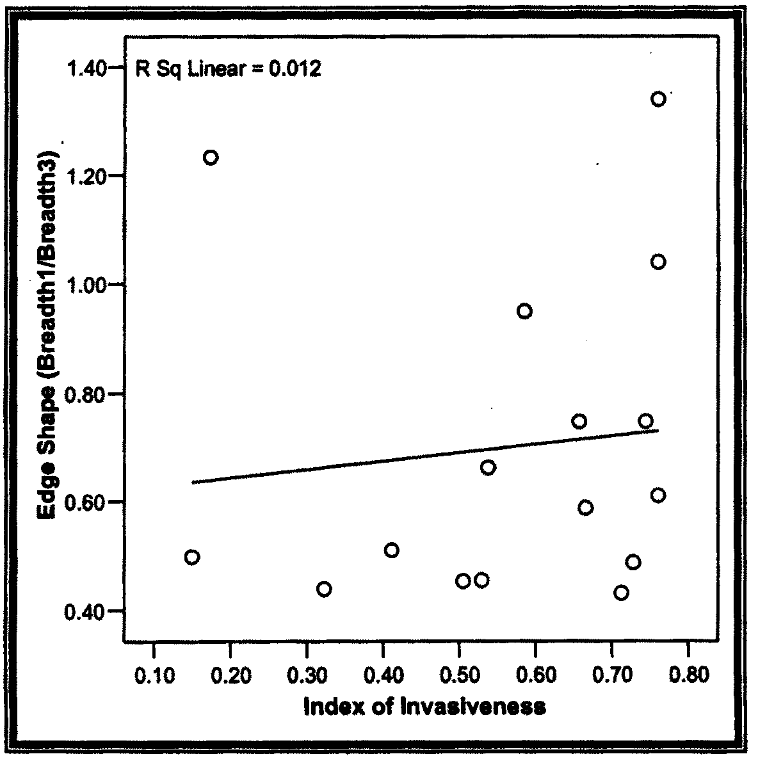

Figure 4.43.13. A scatter plot of index of invasiveness versus edge shape index ratio (breadthl/ breadth3) for large cutting tool types from Lakhmapur.

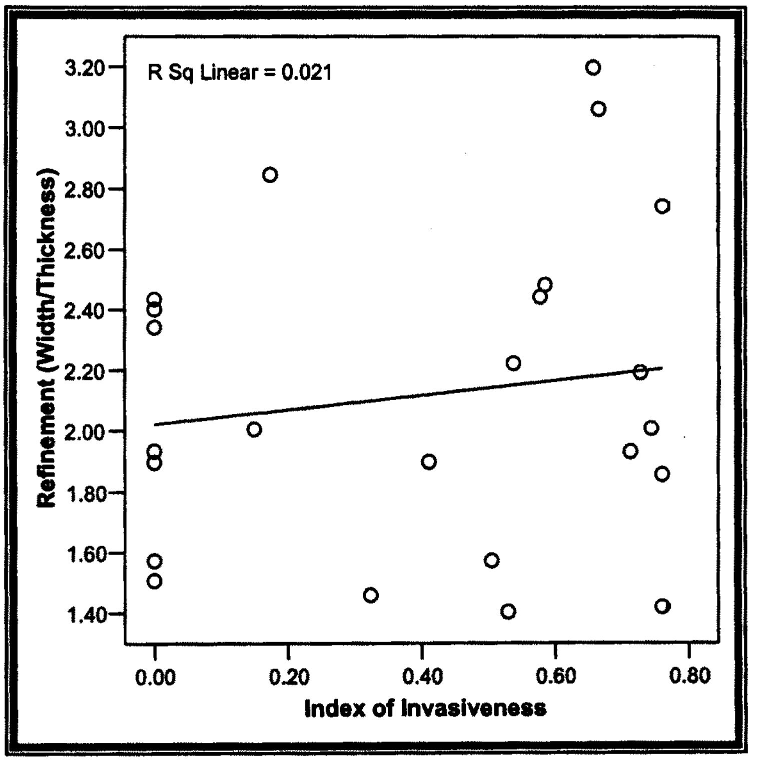

Figure 4.43.14. A scatter plot of index of invasiveness versus refinement index ratio (width/thickness) for large cutting tool types from Lakhmapur.

Non-feather termination.

Total number of non-feather termination is also a measure to measure the reduction process, in which as the reduction advances the non-feather termination count also increases and with that the variability is also shown within the large cutting tools with the comparison of elongation, edge shape and refinement ratio by non-feather termination. Figure 4.43.15., shows discoid was the only large cutting tool which has higher mean value in non-feather termination than the other large cutting tool types.

Figure 4.43.16 to 4.43.118, shows the variability and reduction process within the large cutting tools, with possible increasing in the count of the non-feather termination and increasing reduction process. From Figure 4.43.16., it is clear that when elongation is compared with total count of non-feather termination, as total count of non-feather termination increase, elongation ratio decreases i.e., shorter large cutting tools have high count of non-feather termination and longer large cutting tools have lesser count of non-feather termination. When the total count of non-feather termination is compared with edge shape ratio, it gave a different result from the previous ones, when edge shape ratio is compared to the non-feather termination both of them showed a increasing pattern, i.e., narrower large cutting tools have higher count of non-feather termination and broader large cutting tools have lower count of non-feather termination (see, Figure 4.43.17). Same kind of pattern was noticed when a comparison made between refinement ratio and total count of non-feather termination i.e., as refinement index ratio increase the total count of non-feather termination also increases, indicates that thinner large cutting tools have higher count of non-feather termination and thicker large cutting tools have lower count of non-feather termination (see, Figure 4.43.18). Thus, all these indicate that as the reduction increases, the total count in non-feather termination also increases. When the total count in non-feather termination increases, large cutting tools become shorter, narrower and thinner and this indicates that large cutting tools from Lakhmapur are in early or middle stage reduction.

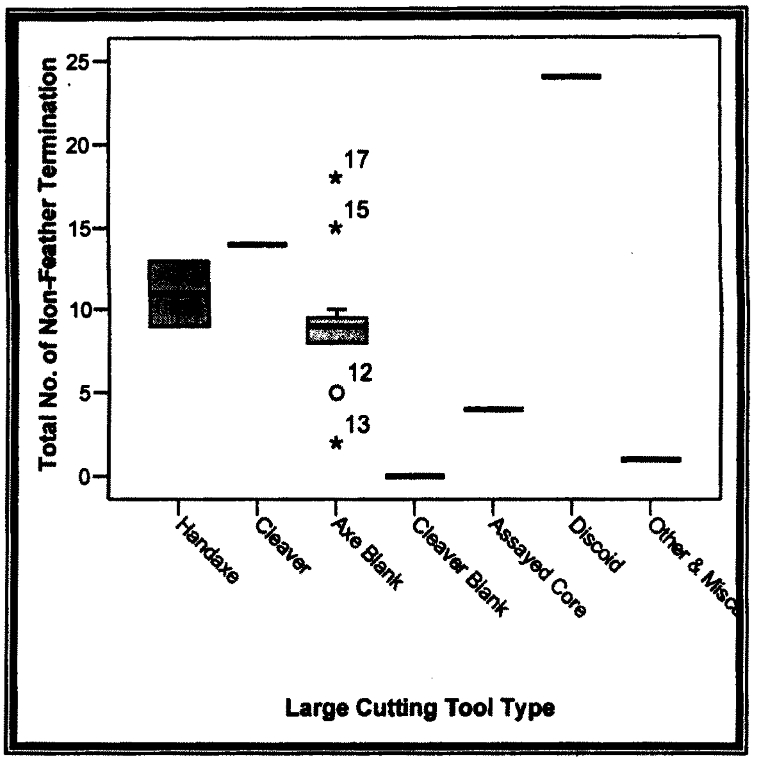

Figure 4.43.15. Box plot of total number of non-feather termination for large cutting tool types from Lakhmapur.

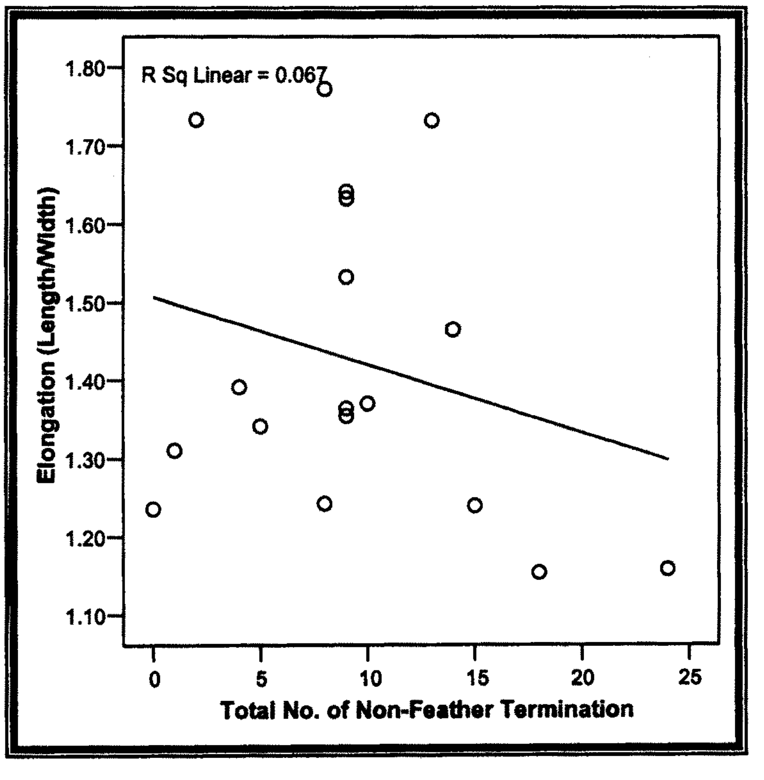

Figure 4.43.16. A scatter plot of total number of non-feather termination versus elongation index ratio (length/width) for large cutting tool types from Lakhmapur.

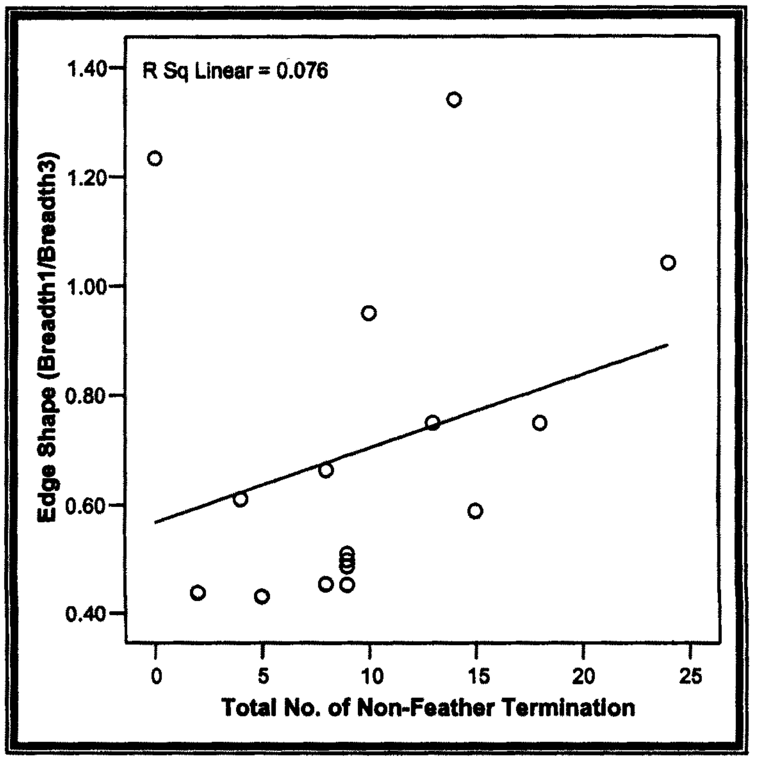

Figure 4.43.17. A scatter plot of total number of non-feather termination versus edge shape index ratio (breadthl/ breadth3) for large cutting tool types from Lakhmapur..

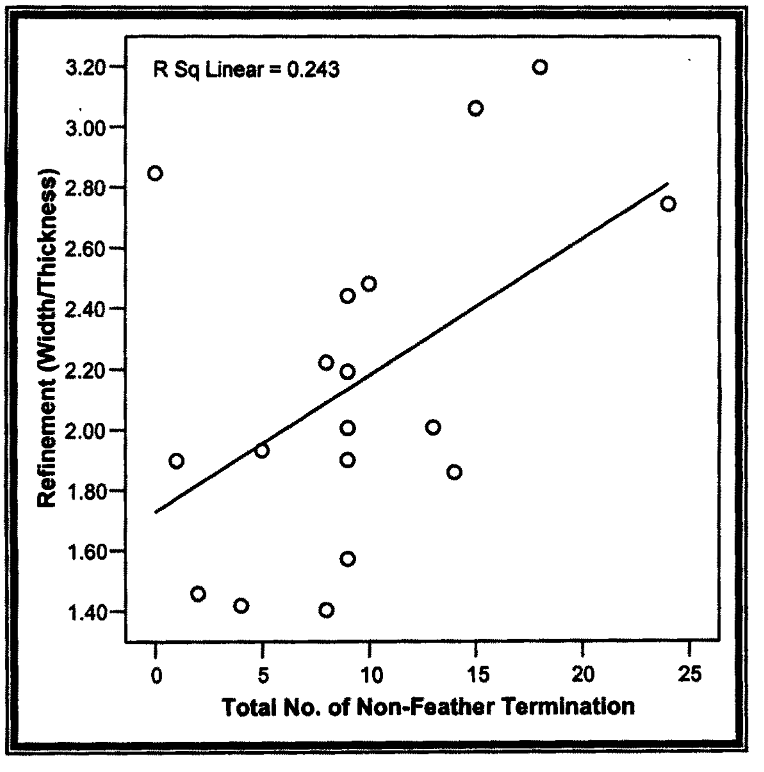

Figure 4.43.18. A scatter plot of total number of non-feather termination versus refinement index ratio (width/thickness) for large cutting tool types from Lakhmapur.

4.44. Choppers types from Lakhmapur

From Lakhmapur a total of 7 chopper were collected, out of these 7, 4 (57.1%) were bifacial choppers and 3 (42.9%) were unifacial choppers (Table--). All choppers from Lakhmapur were made from quartzarenites (quartzite) which has 1/16 to 2 mm grain size.

Table 4.44.1. Frequency of choppers from Lakhmapur.

Chopper Type	Frequency	Percent
Unifacial	3	42.9
Bifacial	4	57.1
Total	**7**	**100**

4.45. Non-metrical attributes for choppers

Common non-metrical attributes of choppers were recorded to find out the good result in non-metrical attributes like tip shape, cross section, profile form, initial form and cortex type with the help of Simple bar, box plots and simple tables.

Tip shape of choppers. The attributes were recorded in order to visualize the tip shape of chopper types. Every tool type has its own tip shape and they are quite different from each other. All choppers had 'G type' tip shape which is wide with a very convex tip, and non breakage in them.

Cross Section of choppers. All choppers from this site had biconvex cross section.

Profile Form of choppers. All 7 choppers which were collected from this site had irregular profile form.

4.46. General metrical measurements for explaining variability among choppers types

General metrical measurements like maximum dimension, maximum width, thickness and weight were recorded in order to explain the size and shape of choppers from Lakhmapur. Mean, standard deviation and coefficient of variation values and simple plots (bar, line, histogram, box and scatter) were applied in order to explain the variability within chopper types size and shape.

Choppers from Lakhmapur vary considerably in size and shape, as explained by mean, standard deviation and coefficient of variation of general metrical measurements (see, Table 4.46.1). Table 4.46.1. and Figure 4.46.1 to 4.46.4., provides a box plot of maximum dimension, maximum width, thickness and weight for all chopper types. Unifacial choppers have higher mean value in maximum dimension (97.67±11.77 mm) and maximum width (79.66± 21.40 mm) and weight (373.33± 86.22 gms) than unifacial chopper, whereas this unifacial chopper which has higher mean value in thickness (49.49±6.55 mm).

Greater variation in the coefficient of variation can be seen in maximum width (CV=0.18).

Table 4.46.1. Mean, standard deviation and coefficient of variation of general metrical measurements for chopper types from Lakhmapur.

Variable	Chopper Type	Mean	Std. Deviation	CV
Maximum Dimension	Unifacial	**97.67**	11.77	0.12
	Bifacial	87.7	10.15	0.12
	Total	92.69	10.96	**0.12**
Maximum Width	Unifacial	**79.66**	21.40	0.27
	Bifacial	70.83	6.09	0.09
	Total	75.25	13.75	**0.18**
Thickness	Unifacial	43.44	6.65	0.15
	Bifacial	**49.49**	6.55	0.13
	Total	46.47	6.60	**0.14**
Weight	Unifacial	**373.33**	86.22	0.23
	Bifacial	273.75	14.36	0.05
	Total	323.54	50.29	**0.14**

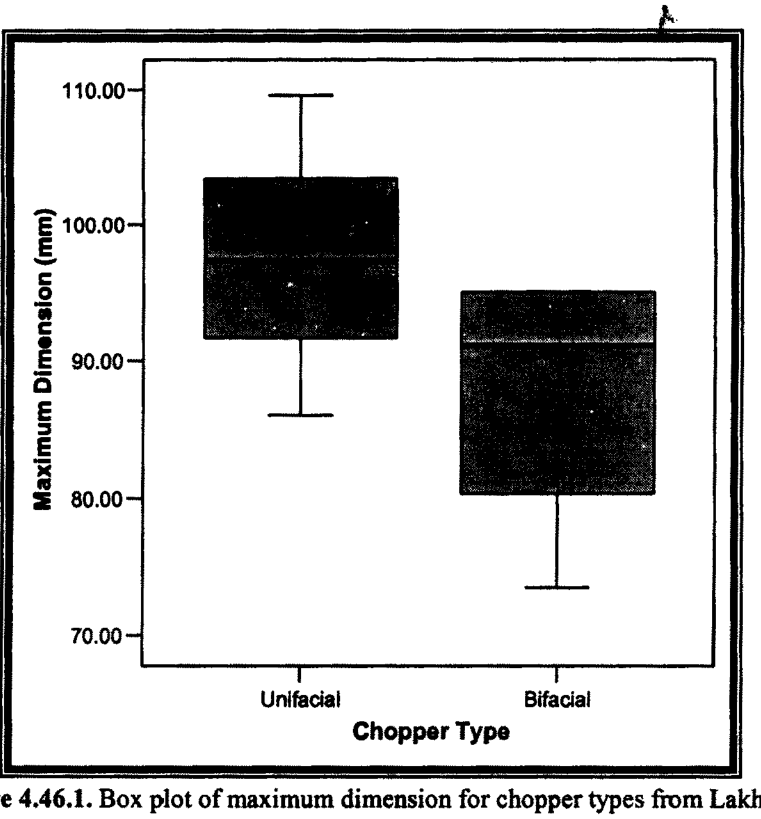

Figure 4.46.1. Box plot of maximum dimension for chopper types from Lakhmapur.

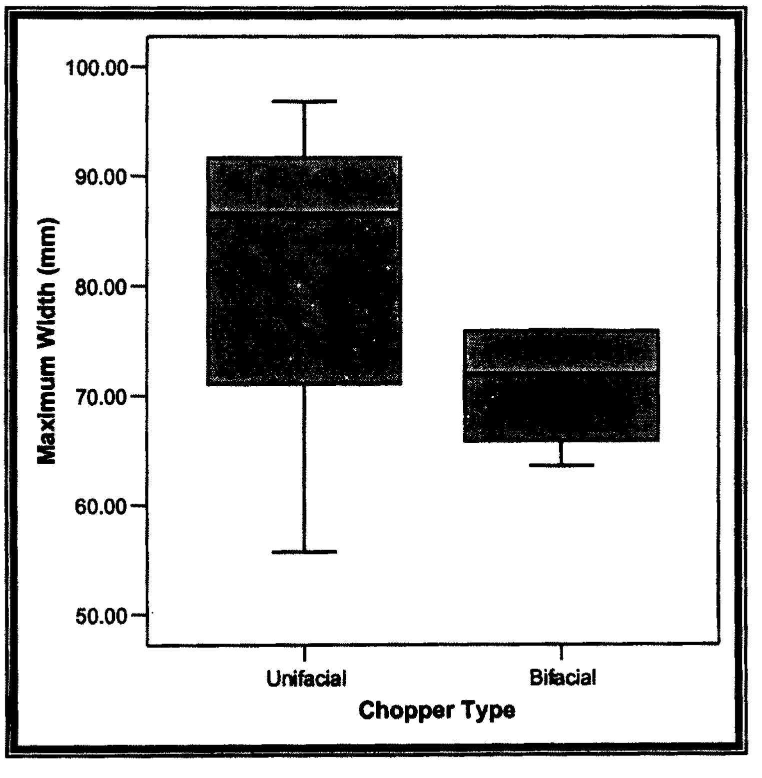

Figure 4.46.2. Box plot of maximum width for chopper types from Lakhmapur.

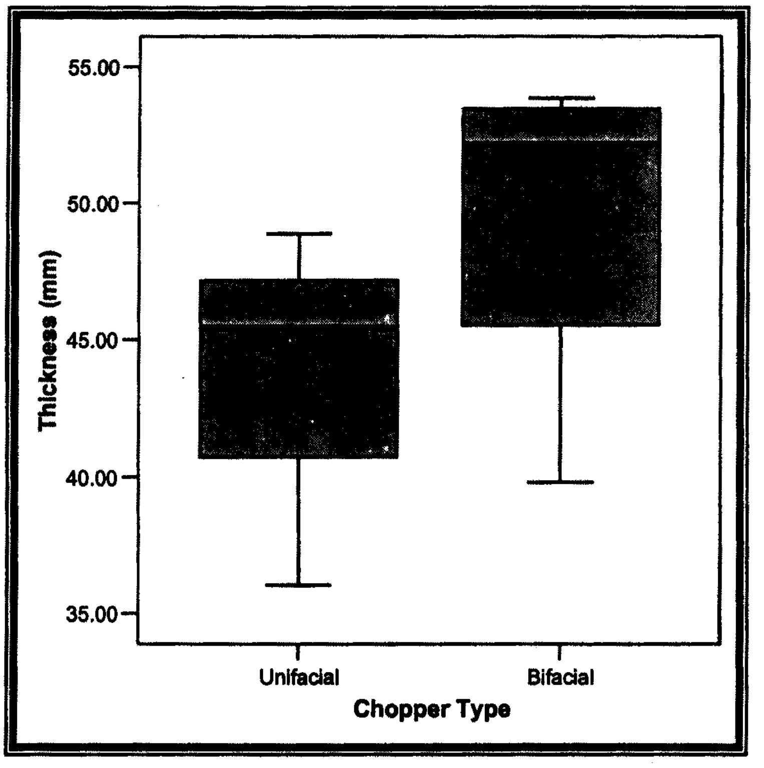

Figure 4.46.3. Box plot of thickness for chopper types from Lakhmapur.

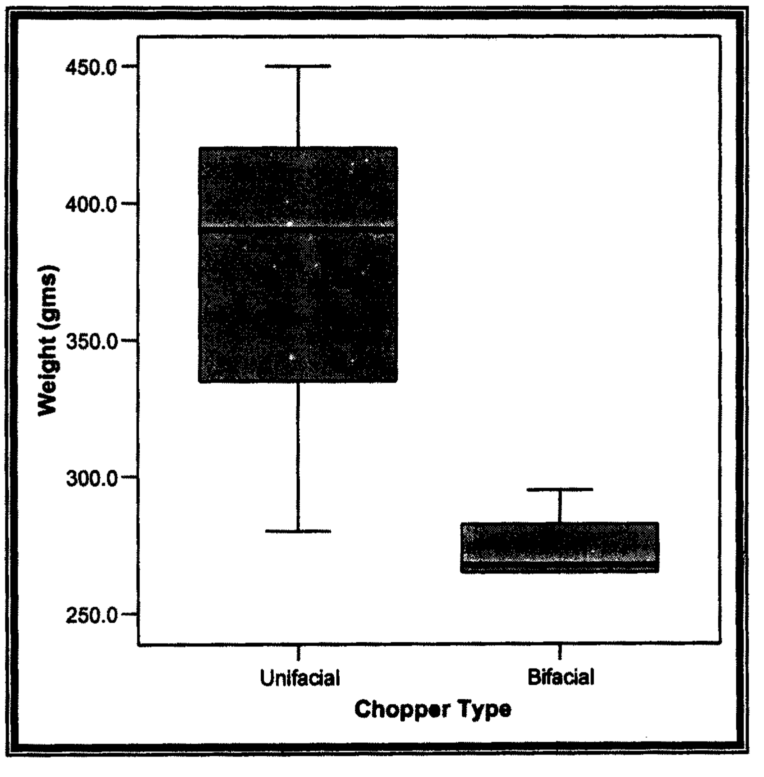

Figure 4.46.4. Box plot of weight for chopper types from Lakhmapur.

4.47. Accessing variability within chopper types

Effects on variability between and within the choppers at Lakhmapur are explained with the help of cortex type and its initial forms.

Influence of raw material on the variability observed in the chopper types

As the chopper from this site were manufactured on only one type of raw material i.e., quartzarenites (quartzite), variability could not be explained with the help of raw material types. Variability in size and shape of raw materials was obtained by the comparison of general linear measurements with the initial form and cortex type of chopper types.

Influence of initial form on the variability observed in the chopper types

Initial forms are the only source for understanding the selection of raw material types by the hominins at this site. Table 4.47.1., is tabulation for initial form of the chopper types. Table 4.47.1., shows blocky, slab, pebble and flake piece are the 4 initial form types which were used to manufacture choppers at this site. From Table 4.47.1., it is clear that flake piece (3) was the major initial form type that was used to manufacture chopper than the blocky (2), pebble type (1) and slab (1). Unifacial choppers (4) were made from all the 4 initial forms types, out of these 2 were made from flake piece, 1 from blocky and another from pebble, while, all 3 bifacial choppers were made from 3 different types of initial form namely blocky, slab and flake piece.

Table 4.47.1. Initial form of chopper types from Lakhmapur.

Initial Form	Chopper Type		Total
	Unifacial	Bifacial	
Pebble	0	1	1
Blocky	1	1	2
Slab	1	0	1
Flake Piece	1	2	3
Total	3	4	7

Table 4.47.2., shows the variation in maximum dimension, maximum width, thickness and weight of two different chopper types made on 4 different initial forms. When a comparison was made on unifacial chopper with its initial form, unifacial choppers made on flake piece was the longest (109.6 mm) and heaviest

(450 gms) and when maximum width and thickness was taken into account, chopper made on slab was the widest (96.80 mm) and the thickness was high (48.87 mm) when they were made on blocky initial form, at the same time, when unifacial chopper were made on blocky initial form, they were shortest (86.07 mm), narrowest (55.67 mm) and lightest (280 gms) and when the thickness is considered, unifacial chopper made on slab were the thinnest (36.03 mm) (Figure 4.47.1 to 4.47.4).

When bifacial choppers were compared with its initial forms, bifacial choppers made on blocky initial form were the longest (95.04 mm), widest (75.95 mm), thickest (53.84 mm) and heaviest (295 gms), at the same time, bifacial choppers made from pebble were the shortest (73.47 mm) and lightest (265 gms) than choppers made from other initial forms. Bifacial choppers made on flake piece were narrower (65.81 mm) and thinner (46.44 mm) (Figure 4.47.1 to 4.47.4).

Table 4.47.2. Mean, standard deviation and coefficient of variation of general metrical measurements for chopper types by its initial form from Lakhmapur.

Chopper Type	Initial Form	Variable	Mean	Std. Deviation	CV
Unifacial	Blocky	Maximum Dimension	86.07	0	0
		Maximum Width	55.67	0	0
		Thickness	48.87	0	0
		Weight	280	0	0
	Slab	Maximum Dimension	97.34	0	0
		Maximum Width	96.80	0	0
		Thickness	36.03	0	0
		Weight	390	0	0
	Flake Piece	Maximum Dimension	109.6	0	0
		Maximum Width	86.51	0	0
		Thickness	45.43	0	0
		Weight	450	0	0
Bifacial	Pebble	Maximum Dimension	73.47	0	0
		Maximum Width	75.75	0	0
		Thickness	51.24	0	0
		Weight	265	0	0
	Flake Piece	Maximum Dimension	91.15	5.41	0.06
		Maximum Width	65.81	3.22	0.05
		Thickness	46.44	9.38	0.20
		Weight	267.5	3.54	0.01
	Blocky	Maximum Dimension	95.04	0	0
		Maximum Width	75.95	0	0
		Thickness	53.84	0	0
		Weight	295	0	0

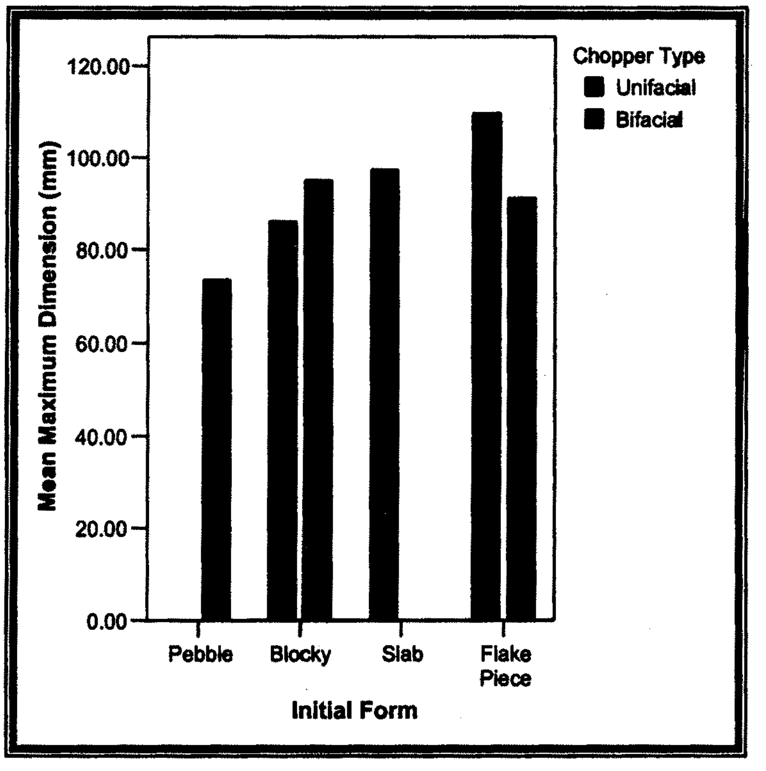

Figure 4.47.1. Bar graph of mean maximum dimension for chopper types by its initial form from Lakhmapur.

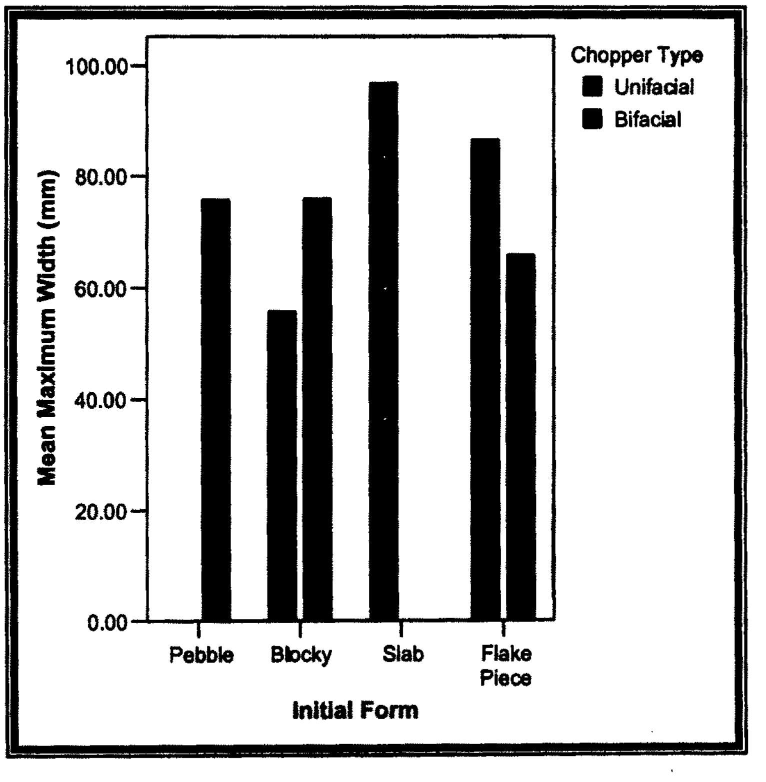

Figure 4.47.2. Bar graph of mean maximum width for chopper types by its initial form from Lakhmapur.

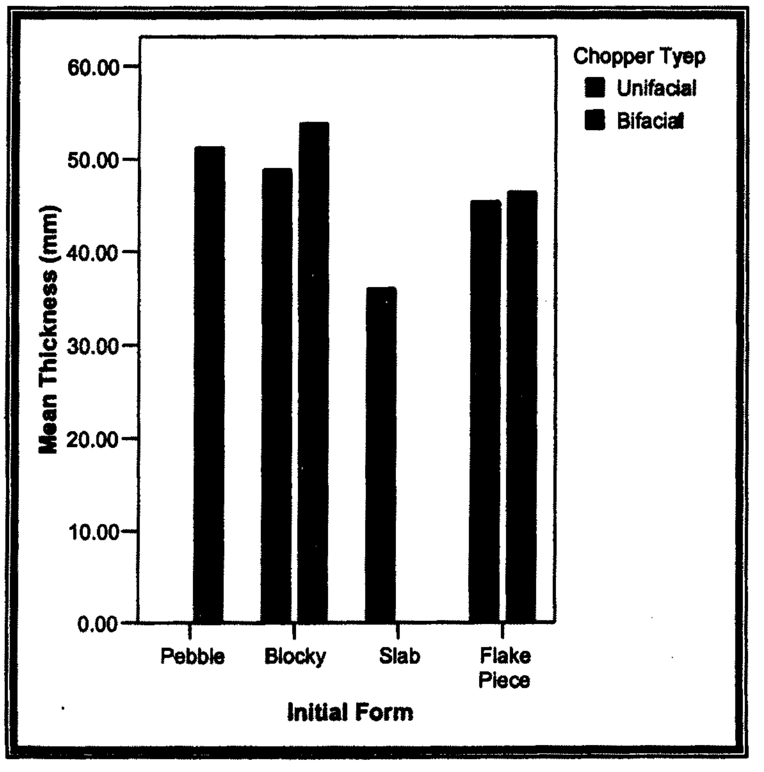

Figure 4.47.3. Bar graph of mean thickness for chopper types by its initial form from Lakhmapur.

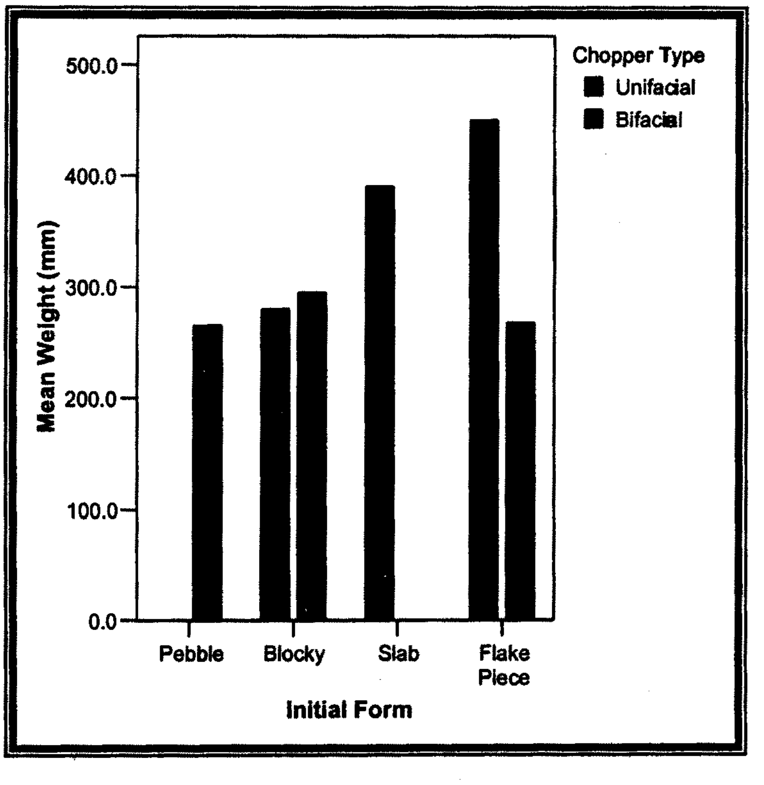

Figure 4.47.4. Bar graph of mean weight for chopper types by its initial form from Lakhmapur.

Influence of cortex type on the variability observed in the chopper types

Out of 6 choppers collected from this site, only 4 gave the information on the cortex type information. From these 4 chopper which had the information on the cortex type, 2 were unifacial and remaining 2 were bifacial choppers. Table 4.47.3., shows that **majority of choppers were made on angular type clast (2), which was followed by sub-angular (1) and sub-rounded (1).** Among these 2 unifacial choppers, 1 was made on angular and another 1 was made from sub-angular and among 2 bifacial choppers, 1 was made on angular and remaining 1 was made from sub-rounded clast type.

Table 4.47.3. Cortex type for chopper types from Lakhmapur.

Cortex Type	**Chopper Type**		**Total**
	Unifacial	**Bifacial**	
Angular	1	1	2
Sub-Angular	1	0	1
Sub-Rounded	0	1	1
Total	2	2	6

Table 4.47.3., shows the exploitation of three clast types (angular, sub-angular and sub-rounded) by the hominins at this site. Table 4.47.4., also shows the variation in maximum dimension, maximum width, thickness and weight of two different chopper types made on 3 different clast types. When comparison was made within the cortex type of chopper types, unifacial chopper made from angular clast type were the longest (97.34 mm), widest (96.8 mm) and heaviest (390 gms), but, the unifacial chopper made from sub-angular clast were the thickest. At the same time when bifacial chopper was compared with its cortex types, bifacial chopper made from angular clast type were longer (95.04 mm), wider (75.95 mm), thicker (53.84 mm) and heavier (295 gms) than bifacial chopper made from sub-rounded clast type.

Table 4.47.4. Mean of general metrical measurements for chopper types by its cortex type from Shankaragatta.

Chopper Type	Cortex Type	Variable	Mean
Unifacial	Angular	Maximum Dimension	97.34
		Maximum Width	96.8
		Thickness	36.03
		Weight	390
	Sub-Angular	Maximum Dimension	86.07
		Maximum Width	55.67
		Thickness	48.87
		Weight	280
Bifacial	Sub-Rounded	Maximum Dimension	73.47
		Maximum Width	75.75
		Thickness	51.24
		Weight	265
	Angular	Maximum Dimension	95.04
		Maximum Width	75.95
		Thickness	53.84
		Weight	295

4.48. Core typology at Lakhmapur

This section will qualitatively and quantitatively explore core types by analyzing its size and shape. Common metrical and non-metrical measurements are analyzed within and between the core types. From this site a total of 51 cores from different localities. Table 4.48.1., provides tabulation for counts of cores from different localities. Locality I was sub-divided into 3 separate localities namely IA, IB and IC, from Locality-I a total of 17 cores were obtained, out of these 17 cores 4 were from IA, 9 were from IB and 4 cores from IC were collected. From Locality-II a total of 10 cores were collected and from Locality-III a total of 24 cores were recovered.

Table 4.48.1. Frequency of cores from different units and spits from Lakhmapur.

Locality	Unit	Spit	Core
IA	1	1	4
	2	1	0
		2	0
IB	1	1	4
		2	5
	2	1	0
	3	1	0
		2	0
IC	1	1	4
II	1	1	0
		2	4
	2	1	3
		2	2
	3	1	1
	4	2	0
III	1	1	0
		2	3
	2	1	4
		2	2
	3	1	3
		2	10
	4	2	2
Total			**51**

4.49. Core Types

Table 4.49.1., provides the frequency of core types that were collected from the excavation. Lakhmapur site yielded 51 cores of 3 types namely multi-platform, levallois and bipolar core. Out of the 51 cores, 48 (94.1%) were multi-platform, 2 (3.9%) were bipolar and 1 (2%) was levallois core. Figure 4.49.1., shows that, majority of cores were of multi-platform core type and other were in very few counts.

Table 4.49.1. Frequency of core types from Lakhmapur.

Core Type	Frequency	Percent
Multi-Platform Core	48	94.1
Bipolar Core	2	3.9
Levallois core	1	2
Total	**51**	**100**

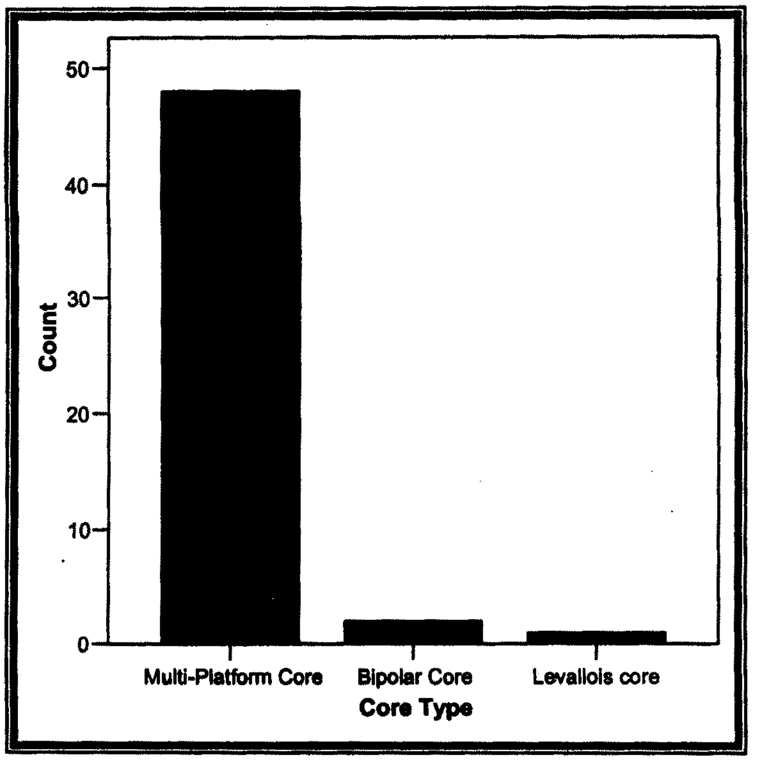

Figure 4.49.1. Bar graph for core types from Lakhmapur.

Table 4.49.2., provides the frequency of core at this site, which was used to remove flakes or blades. From Table 4.49.2., it is clear that majority (94.1%) of core was used for flake removal and minimum percentage (5.9%) of core was used for blades removal (Figure 4.49.2).

Table 4.49.2. Frequency of core types from Lakhmapur.

Core Type	Frequency	Percent
Blade Core	3	5.9
Flake Core	48	94.1
Total	**51**	**100**

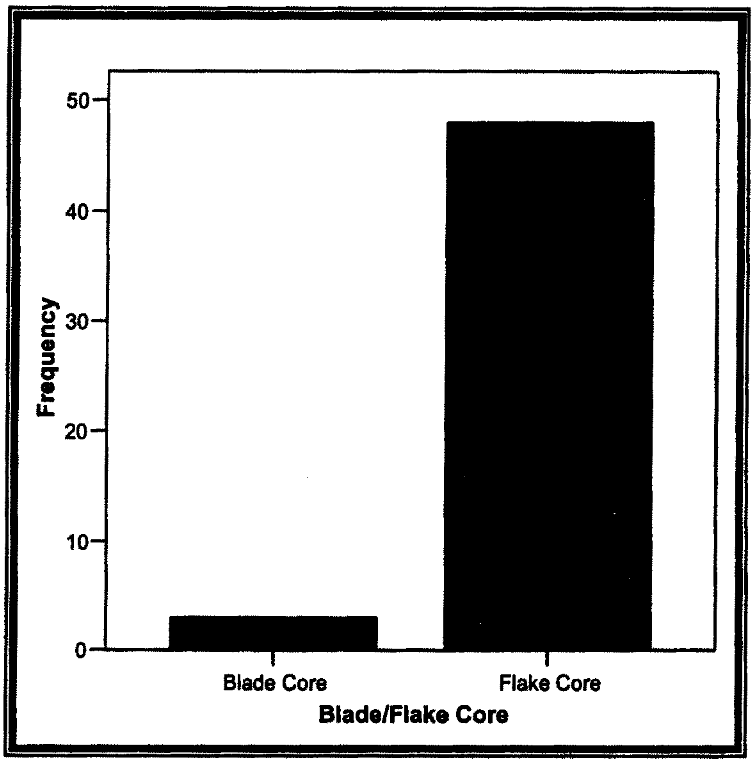

Figure 4.49.2. Bar graph for core types from Lakhmapur.

4.50. Non-metrical attributes for core types

Common non-metrical attributes were recorded for core types, with the help of simple bar, box plots and simple tables were used in order to explain these non-metrical attributes.

Raw Material types

Table 4.50.1., provides tabulation for lithic assemblage composition by core types and raw material types. Proportions are in parenthesis by column. From Table 4.50.1., it is clear that the most preferred raw material at this site was quartzarenites (quartzite) (49) having 1/16 to 2 mm grain size than other raw material type having <1/16 mm grain size like quartz (1) and chert (1). As the majority of cores were of multi-platform core (48), out of these 48 multi-platform cores, 47 (97.9%) were from quartzarenites (quartzite) having 1/16 to 2 mm grain size and only 1 (2.1%) was from chert with <1/16 mm grain size (Figure 4.50.1). Bipolar which are 2 in count, out of these 2, 1was made from quartzarenites (quartzite) and another which was made from quartz, whereas the levallois core which was in minimum count (n=1) was made from quartzarenites (quartzite).

Table 4.50.2., shows the relationship between core types. From 48 flake cores, majority of them were made from quartzarenites (quartzite) (47) and only 1 flake core was made from chert. Very few blade cores (3) were recovered from this site, from these 3 blade core, 2 were made from quartzarenites (quartzite) and only one was made from quartz.

Hence, from Table 4.50.1 and 4.50.1., it is clear that the hominins at this site were reducing flakes from multi-platform cores which was made on quartzarenites (quartzite) and other raw like quartz and chert were rarely used.

Table 4.50.1. Core types broken down by raw material types from Lakhmapur.

Raw Material	Core Type			Total
	Multi-Platform Core	Bipolar Core	Levallois core	
Quartzarenites (quartzite)	47 (97.9)	1 (50)	1 (100)	49 (96)
Quartz	0 (0.0)	1 (50)	0	1 (2)
Chert	1 (2.1)	0	0	1 (2)
Total	**48**	**2**	**1**	**51**

Table 4.50.2. Core types broken down by raw material types from Lakhmapur.

Raw Material	Blade/Flake Core		Total
	Blade Core	Flake Core	
Quartzarenites (quartzite)	2 (66.6)	47 (97.9)	49 (96.1)
Quartz	1 (33.3)	0 (0.0)	1 (1.9)
Chert	0 (0.0)	1 (2.1)	1 (1.9)
Total	**3**	**48**	**51**

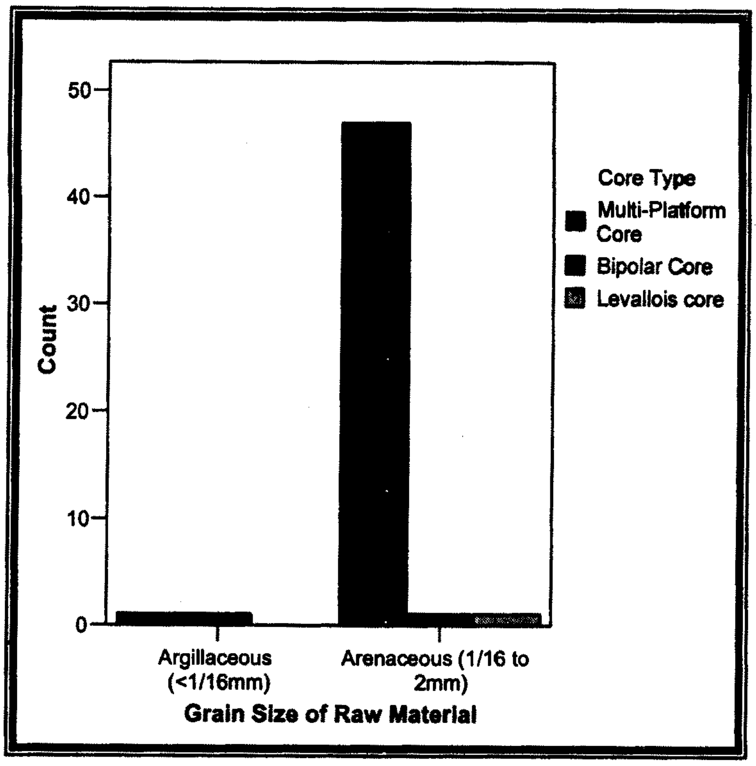

Figure 4.50.1. Bar graph for core types broken down by raw material types from Lakhmapur.

Cortex type

From 51 cores, 33 (64.7%) had the information on the cortex type. Majority of core were made on angular (12) and was followed by sub-rounded (9), sub-angular (6), rounded (3) and indeterminate (3) (Table 4.50.3).

Table 4.50.3. Core types broken down by cortex types from Lakhmapur.

Cortex Type	Frequency	Percent
Angular	12	36.4
Sub-Angular	6	18.2
Sub-Rounded	9	27.3
Rounded	3	9.1
Indeterminate	3	9.1
Total	**33**	**100**

As said before 33 cores had information on cortex type, out of these 33 cores, 31 (93.9%) are multi-platform core and 2 (6.1%) are bipolar cores (Table 4.50.4). Among these 31 multi-platform core, 11 (35.5%) were made from angular clast type, 9 (29.1%) were made from sub-rounded, 6 (19.4%) were of sub-angular, 3 (9.7%) are from indeterminate and remaining 2 (6.5%) were made from rounded clast type (Figure 4.50.2). At the same time, flake core, which are in majority (32) were made from 11 (34.4%) angular clast, 9 (28.1%) sub-rounded, 6 (18.7%) sub-angular, 3 (9.4%) rounded and 3 (9.4%) indeterminate (Table 4.50.5).

Therefore, Table 4.50.5 and Figure 4.50.2. and 4.50.3., indicates that angular and sub-rounded type of clast was used in majority in order to detach flakes from the core.

Table 4.50.4. Core types broken down by cortex types from Lakhmapur.

Cortex Type	Typology for Core		Total
	Multi-Platform Core	Bipolar Core	
Angular	11 (35.5)	1 (50)	12
Sub-Angular	6 (19.4)	0 (0.0)	6
Sub-Rounded	9 (29.1)	0 (0.0)	9
Rounded	2 (6.5)	1 (50)	3
Indeterminate	3 (9.7)	0 (0.0)	3
Total	**31 (93.9)**	**2 (6.1)**	**33**

Table 4.50.5. Core types broken down by cortex types from Lakhmapur.

Cortex Type	Blade/Flake Core		Total
	Blade Core	Flake Core	
Angular	1 (100)	11 (34.4)	12
Sub-Angular	0 (0.0)	6 (18.7)	6
Sub-Rounded	0 (0.0)	9 (28.1)	9
Rounded	0 (0.0)	3 (9.4)	3
Indeterminate	0 (0.0)	3 (9.4)	3
Total	**1**	**32**	**33**

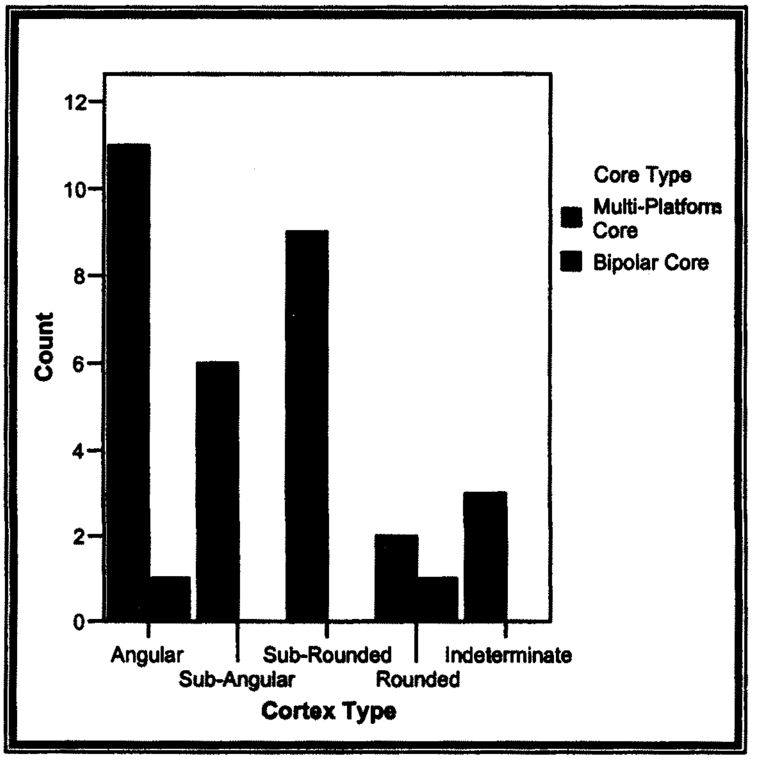

Figure 4.50.2. Bar graph for core types broken down by cortex types from Lakhmapur.

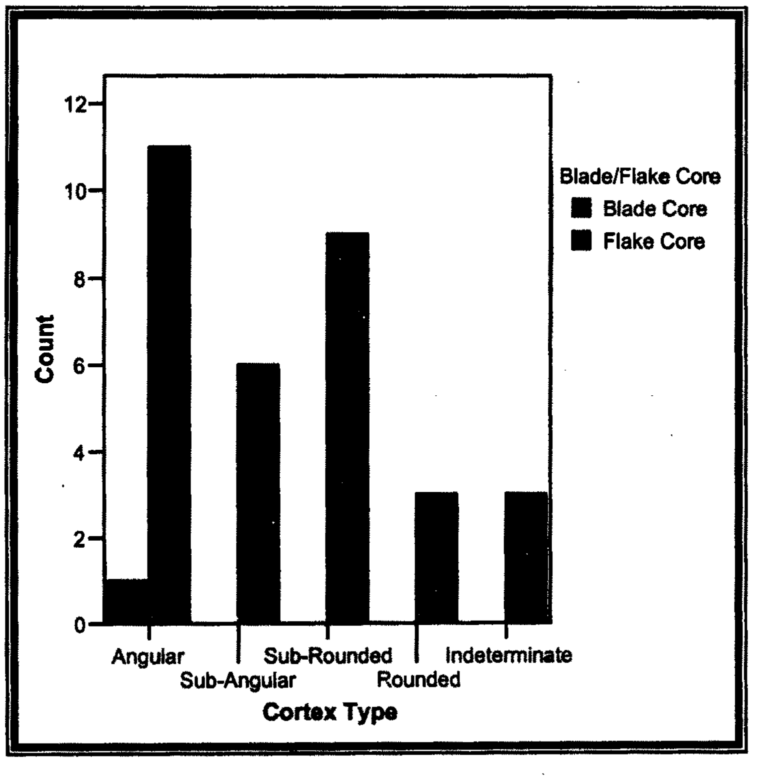

Figure 4.50.3. Bar graph for core types broken down by cortex types from Lakhmapur.

Platform Surface

From 51 cores, 29 had information on platform surface. Out of these 29 platforms surface information, 2 (6.9%) had cortical surface, 6 (20.7%) had single conchoidal, 20 (68.9%) had multi conchoidal and only 1 had crushed platform surface. As the multi-platform core is higher in number, it retains the highest amount of information on platform surface. Table 4.50.6., reveals that flakes removed from multi-platform core have, 19 (73.1%) multi conchoidal platforms, 6 (23.1%) single conchoidal and another 1 (3.8%) had cortical platform surface, whereas, bipolar cores are 2 in counts, they had 1 (50%) cortical and 1 (50%) crushed, and levallois core which is minimum count (n=1) had 1 (100%) multi-platform (Table 4.50.6). Blades from core were also removed at this site and these cores had 1 single conchoidal, 1 multi conchoidal and 1 cortical platform (Table 4.50.7).

Hence all this indicate that majority of flakes and blades were removed from cores which had been prepared by removing multiple flakes from the platform (multi conchoidal platform) (Figure4.50.4 and Figure 4.50.5).

Table 4.50.6. Platform surface for cores from Lakhmapur.

Platform Surface	Frequency	Percent
Single Conchoidal	6	20.7
Multiple Conchoidal	20	68.9
Cortical	2	6.9
Crushed	1	3.4
Total	29	100

Table 4.50.7. Core types broken down by platform surface from Lakhmapur.

Platform Surface	Typology for Core			Total
	Multi-Platform Core	**Bipolar Core**	**Levallois core**	
Single Conchoidal	6 (23.1)	0 (0.0)	0 (0.0)	6
Multiple Conchoidal	19 (73.1)	0 (0.0)	1 (100)	20
Cortical	1 (3.8)	1 (50)	0 (0.0)	2
Crushed	0 (0.0)	1 (50)	0 (0.0)	1
Total	26 (89.6)	2 (6.9)	1 (3.4)	29

Table 4.50.8. Core types broken down by platform surface from Lakhmapur.

Platform Surface	Blade/Flake Core		Total
	Blade Core	Flake Core	
Single Conchoidal	1	5	6
Multiple Conchoidal	1	19	20
Cortical	1	1	2
Crushed	0	1	1
Total	**3**	**26**	**29**

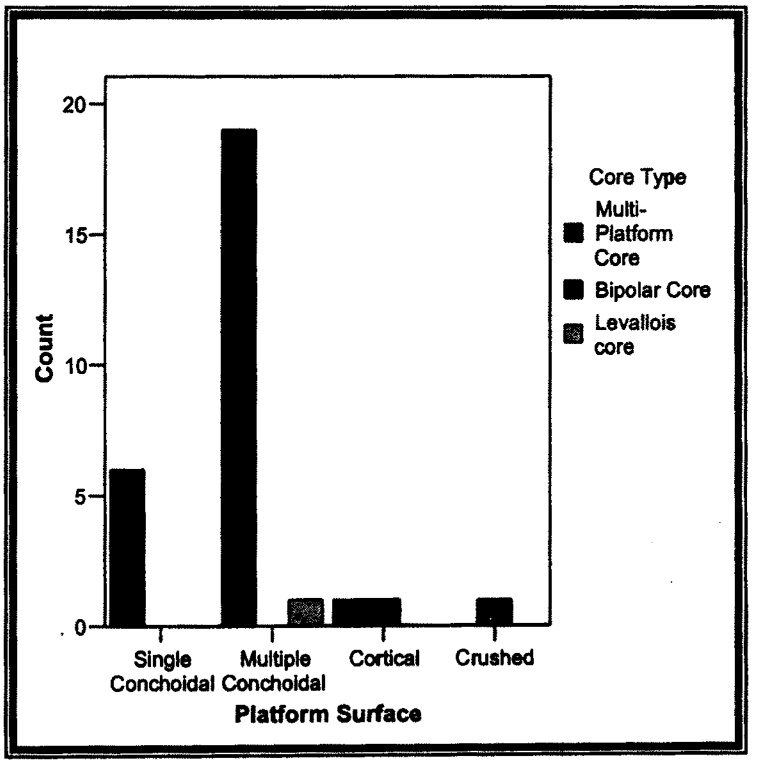

Figure 4.50.4. Bar graph for core types broken down by platform surface from Lakhmapur.

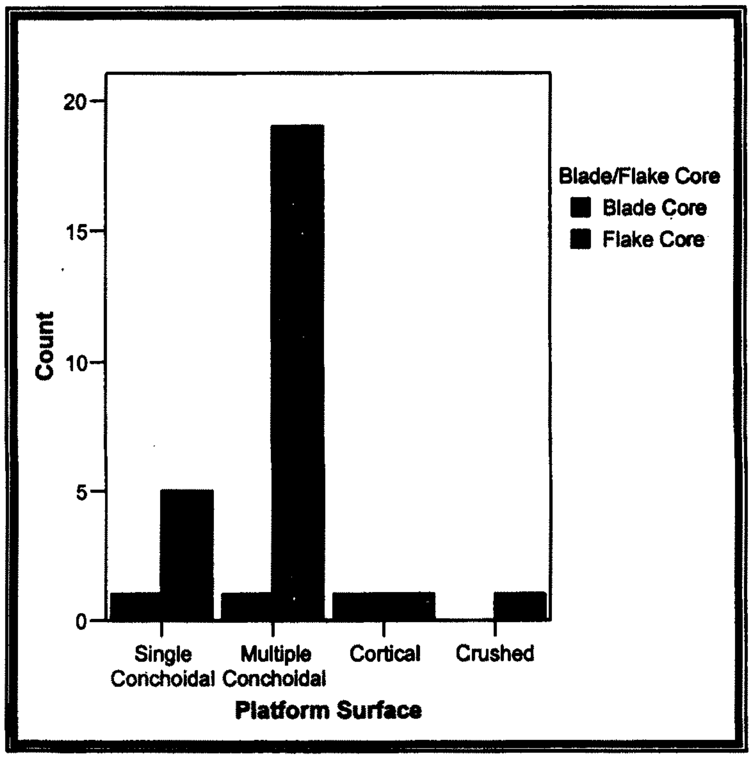

Figure 4.50.5. Bar graph for core types broken down by platform surface from Lakhmapur.

4.51. General metrical measurements for core type

Several important attributes were recorded in order to explain the variability within the core type common metrical attributes like maximum dimension, maximum width, thickness and weight were recorded in order to measure the shape and size of core.

From Table 4.51.1., it is clear that the multi-platform cores are the longest (81.25 mm), widest (66.81 mm), thickest (49.48 mm) and heavier (347.24 gms) and these cores were followed by bidirectional core and bipolar core. Bipolar cores were the smallest when the length of the core is (39.94 mm), width is (33.93 mm), thickness is (18.16 mm) and weight is (26.25 gms) than levallois core.

Hence, Table 4.51.1 **and Figure 4.51.1 to 4.51.4** indicates those multi-platforms were the biggest core and had more variation from all other core types.

Table 4.51.1. Mean, standard deviation and coefficient of variation of general metrical measurements for cores types from different phases at Lakhmapur.

Core Type	Variable	Mean	Std. Deviation	CV
Multi-Platform Core	Maximum Dimension	81.25	20.97	0.26
	Maximum Width	66.81	19.19	0.29
	Thickness	49.48	16.00	0.32
	Weight	347.24	414.42	1.19
Bipolar Core	Maximum Dimension	39.94	8.62	0.22
	Maximum Width	33.93	13.68	0.40
	Thickness	18.16	2.94	0.16
	Weight	26.25	13.65	0.52
Levallois core	Maximum Dimension	66.18	0	0
	Maximum Width	56.31	0	0
	Thickness	28.62	0	0
	Weight	104.6	0	0

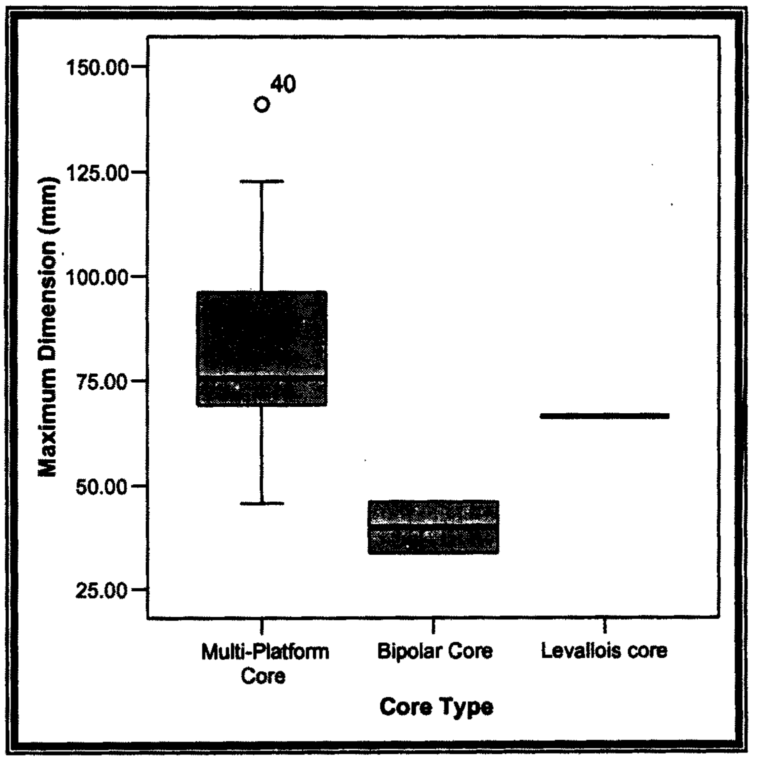

Figure 4.51.1. Box plot of maximum dimension for core types from Lakhmapur.

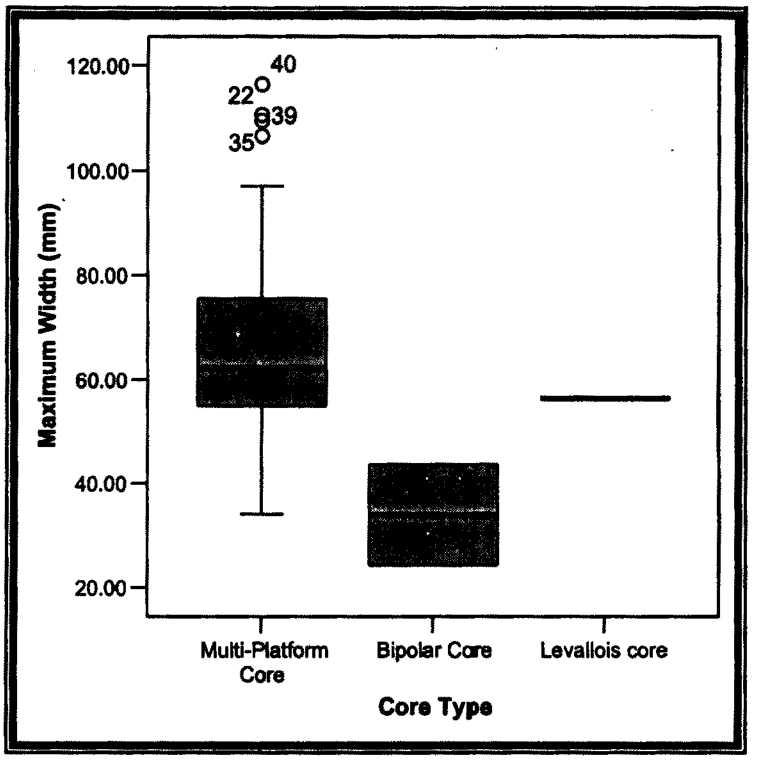

Figure 4.51.2. Box plot of maximum width for core types from Lakhmapur.

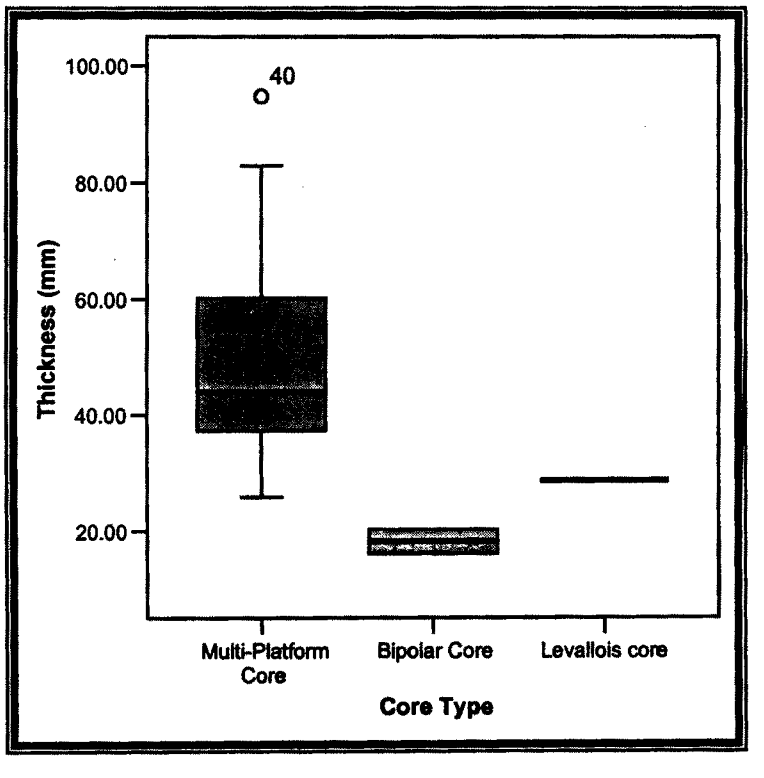

Figure 4.51.3. Box plot of thickness for core types from Lakhmapur.

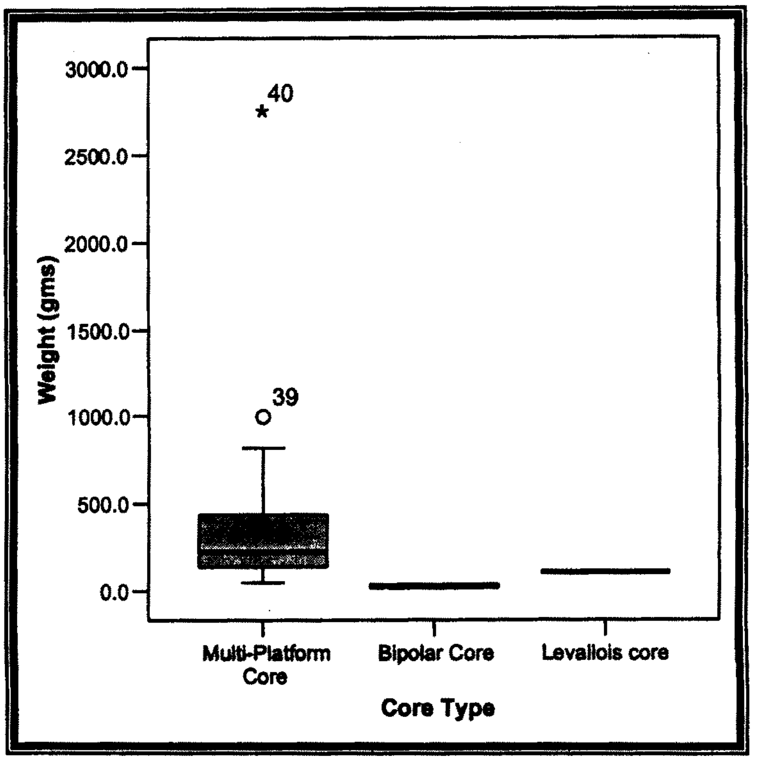

Figure 4.51.4. Box plot of weight for core types from Lakhmapur.

Other type of core which gave the information on the blanks removed from the cores which were collected from this site, were compared with their common metrical attributes like maximum dimension, maximum width, thickness and weight, and other variable like scar>15mm, total flake scar count, longest face, number of rotations, number of non-feather termination, number of elongated parallel scars, last platform angle, number of platform quadrants and longest flake removed.

Table 4.51.2., shows that flake cores are the longest (80.89 mm), widest (66.60 mm), thickest (48.78 mm) and heavier (345.20 gms) (Figure 4.51.5 to 4.51.8) and whereas, flake & blade core are shorter (54.55 mm), narrower (44.69 mm), thinner (32.62 mm) and lighter (85.03 mm) than flake core (Figure 4.51.5 to 4.51.8).

Table 4.51.2. Mean, standard deviation and coefficient of variation of general metrical measurements for cores types from different phases at Lakhmapur.

Core Type	Variable	Mean	Std. Deviation	CV
Blade Core	Maximum Dimension	54.55	17.94	0.33
	Maximum Width	44.69	17.95	0.40
	Thickness	32.62	14.74	0.45
	Weight	85.03	64.90	0.76
Flake Core	Maximum Dimension	80.89	21.44	0.27
	Maximum Width	66.60	19.38	0.29
	Thickness	48.78	16.73	0.34
	Weight	345.20	415.71	1.20

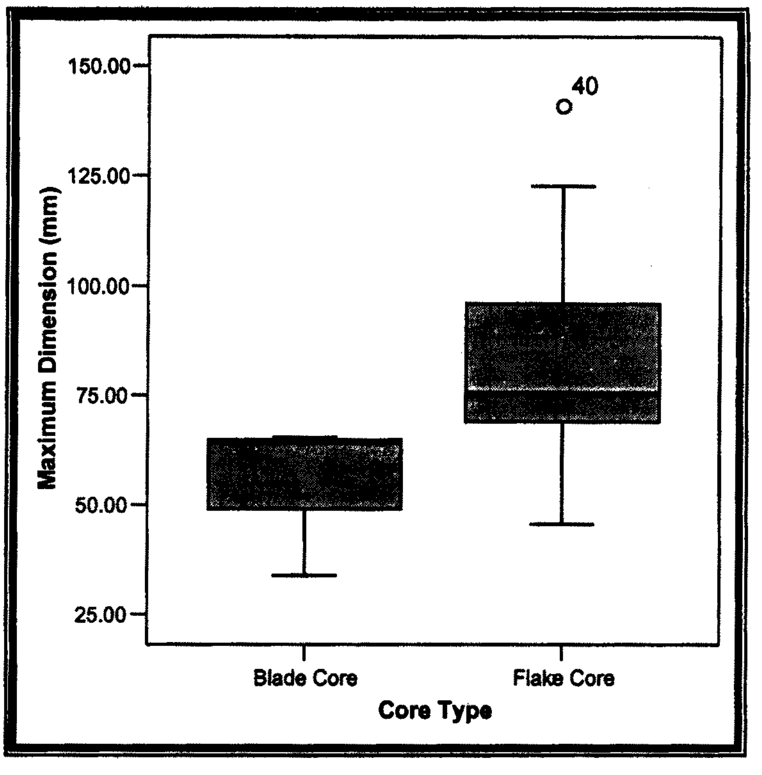

Figure 4.51.5. Box plot of maximum dimension for core types from Lakhmapur.

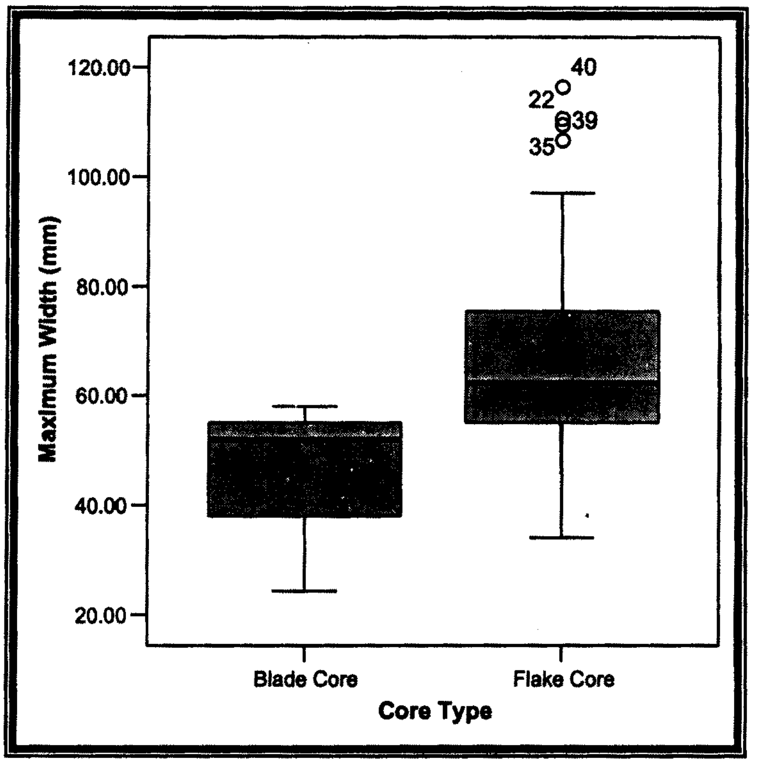

Figure 4.51.6. Box plot of maximum width for core types from Lakhmapur.

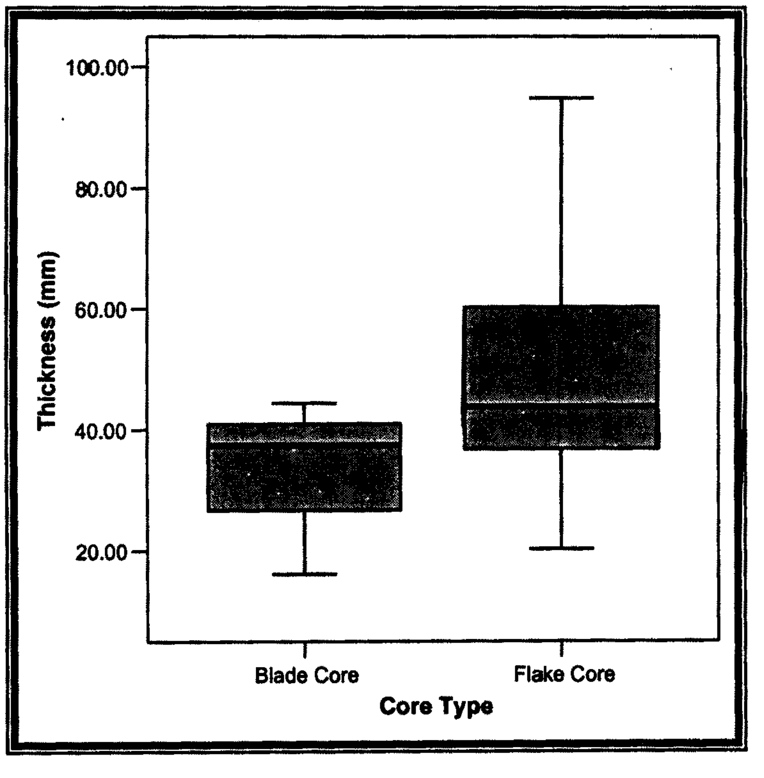

Figure 4.51.7. Box plot of thickness for core types from Lakhmapur.

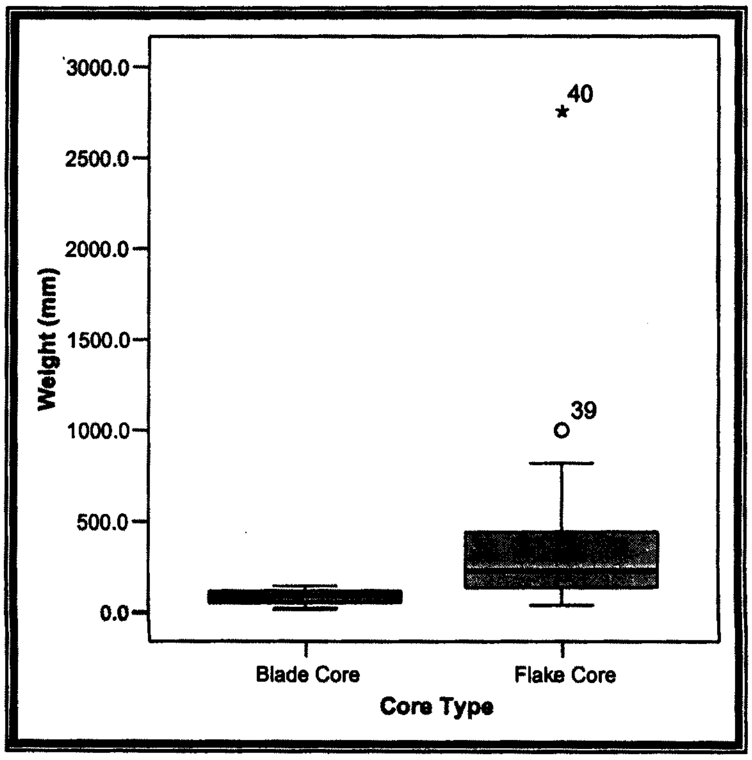

Figure 4.51.8. Box plot of weight for core types from Lakhmapur.

4.52. Additional metrical measurements for core types

Additional metrical measurements were taken in order to measure variability observed within the core types. Table 4.52.1., provides a comparison of core types by its variables which explain about the flake removed from the respective cores types. From Table 4.52.1., it is clear that bipolar core has the lowest mean value in almost all variables like scar>15mm (1.5), longest face (36.93), number of rotations (2), number of non feather termination (0), last platform angle (78) and total flake scar count (1.5), except number of elongated parallel scars (1) and number of platform quadrants (1.5) than the other two types namely multi-platform and levallois core, because the scar>15mm (7), total scar count (15), number of rotations (9), number of non-feather, last platform angle (90) and number of platform quadrants (5) of levallois core are greater, when compared with multi-platform and multi-platform bola cores, and whereas, longest face (71.25 mm), elongated parallel scars (3.67) and longest flake removed (45.57 mm) of multi-platform core are greater than the values of levallois and bipolar core. This result should be cautiously taken because levallois core are in the least count (n=1). Therefore Table 4.52.1., indicate that maximum amount of reduction took place on levallois and multi-platform core, because as reduction increases, the total flake scar count, number of

non feather termination and last platform angle also increases, whereas, scar count>15mm, longest face and longest flake removed decreases.

Table 4.52.1. Mean, standard deviation and coefficient of variation of additional metrical measurements for cores types from different phases at Lakhmapur.

Core Type	Variable	Mean	Std. Deviation	CV
Multi-Platform Core	Scars>15mm	5.56	2.62	0.47
	Total Flake Scar Count	6.33	3.28	0.52
	Longest Face	71.25	21.71	0.30
	Number of Rotations	4.38	2.48	0.57
	No. Non-Feather Termination	2.26	2.24	0.99
	No. Elongate Parallel Scars	3.67	1.78	0.48
	Last Platform Angle	84.67	10.47	0.12
	No. of Platform Quadrants	3.59	1.36	0.38
	Longest Flake Removed	45.57	12.49	0.27
Bipolar Core	Scars>15mm	1.5	0.71	0.47
	Total Flake Scar Count	1.5	0.71	0.47
	Longest Face	36.93	4.37	0.12
	Number of Rotations	2	0	0
	No. Non-Feather Termination	0	0	0
	No. Elongate Parallel Scars	1	0	0
	Last Platform Angle	78	9.90	0.13
	No. of Platform Quadrants	1.5	0.71	0.47
	Longest Flake Removed	26.77	3.25	0.12
Levallois core	Scars>15mm	7	0	0
	Total Flake Scar Count	15	0	0
	Longest Face	65.22	0	0
	Number of Rotations	9	0	0
	No. Non-Feather Termination	5	0	0
	No. Elongate Parallel Scars	0	0	0
	Last Platform Angle	90	0	0
	No. of Platform Quadrants	5	0	0
	Longest Flake Removed	42.81	0	0

Table 4.52.2., provides a comparison of core types by its variables which explain about the blanks removed from the respective cores types. From Table 4.52.2., it is clear that flake core has the high mean value in variables like total scar count (6.33) longest face (71.18 mm), number of non feather termination (2.24), last

platform angle (84.94), number of platform quadrants (3.61) and longest flake removed (45.19 mm), as they have high mean value in maximum dimension, maximum width, thickness and weight, and at the same time these flake cores have low mean value for scar>15mm (5.42), number of rotations (4.39) and number of elongated parallel scars (3) than blade core. As the blade cores at this site have high mean value for scar>15mm (5.67), number of rotations (4.39) and number of elongated parallel scars (3), indicates that these blade core were given more care when reduction was in progress in order to maximize the number of blanks removed from the core. Therefore Table 4.52.2., indicate that flakes were removed by using multiple platform in order to maximize the amount of flakes removed from the core. At the same time when blades were removed from the multi-platform core, these cores where rotated in many times in order to get a new platform and this resulted in more number of scars>15mm and more elongated parallel scars.

Table 4.52.2. Mean, standard deviation and coefficient of variation of additional metrical measurements for cores types from different phases at Lakhmapur.

Core Type	Variable	Mean	Std. Deviation	CV
Blade Core	Scars>15mm	5.67	4.16	0.73
	Total Flake Scar Count	6	4.36	0.73
	Longest Face	47.53	12.10	0.25
	Number of Rotations	6.5	6.36	0.98
	No. Non-Feather Termination	2	2	1
	No. Elongate Parallel Scars	5	3.46	0.69
	Last Platform Angle	77.67	7.02	0.09
	No. of Platform Quadrants	2.33	1.53	0.65
	Longest Flake Removed	38.08	8.47	0.22
Flake Core	Scars>15mm	5.42	2.62	0.48
	Total Flake Scar Count	6.33	3.55	0.56
	Longest Face	71.18	21.92	0.31
	Number of Rotations	4.39	2.38	0.54
	No. Non-Feather Termination	2.24	2.28	1.02
	No. Elongate Parallel Scars	3	0.94	0.31
	Last Platform Angle	84.94	10.44	0.12
	No. of Platform Quadrants	3.61	1.37	0.38
	Longest Flake Removed	45.19	12.84	0.28

4.53. Accessing variability within core types

Variability between and within the core types will be explained with the help of variability in raw materials (i.e., types, size and shape) and stages of reduction in the upcoming analysis.

Influence of cortex type on the variability observed in the core types

This section of analysis examines the frequency of core types manufactured on specific raw material types. The hypothesis being tested is that raw material physical differences are reflected in core type's general linear measurement. At Lakhmapur, majority of core types were manufactured only on quartzarenites (quartzite) (96%), 1 (2%) on quartz and 1 (2%) on chert. (see Table 4.53.1). Due to the low count in different varieties of raw material types, no statistical analysis could be done. For this reason, raw material type could not explain the variability observed in morphology of core types. Hence, in order to test the effects on size and shape of raw material on the variability in morphology of core types, initial form and cortex type of core types were compared with general linear measurements (see Figure 4.53.1).

Table 4.53.1., indicates that multi-platform core made from sub-angular are longer (95.78 mm) and thicker (58.02 mm), at the same time when multi-platform core are made from indeterminate are wider (78.26 mm). When weight is taken into account for the multi-platform cores, then multi-platform core made from angular clast types are the heaviest (601.42 gms). While multi-platform core made from sub-rounded are the shortest (77.80 mm) and narrowest (61.72 mm), at the same time when these cores are made from rounded clast types they are thinnest (43.02 mm) and lightest (291.30 gms). Whereas, bipolar cores which had the information on the cortex type were minimum in count (n=1), and they are made from rounded clast type.

Hence, Table 4.53.1 and Figure 4.53.1 to 4.53.4., indicates that multi-platform core made from sub-angular and angular clast are bigger than multi-platform core made from sub-rounded and rounded clast type.

Table 4.53.1. Mean, standard deviation and coefficient of variation for general metrical measurements of core types from different phases broken down by cortex type from Lakhmapur.

Core Type	Cortex Type	Variable	Mean	Std. Deviation	CV
Multi-Platform Core	Angular	Maximum Dimension	90.72	26.51	0.29
		Maximum Width	72.01	25.42	0.35
		Thickness	55.72	19.19	0.34
		Weight	601.42	766.10	1.27
	Sub-Angular	Maximum Dimension	95.78	15.46	0.16
		Maximum Width	76.02	19.96	0.26
		Thickness	58.02	15.47	0.27
		Weight	427.87	187.15	0.44
	Sub-Rounded	Maximum Dimension	77.80	19.45	0.25
		Maximum Width	61.72	15.53	0.25
		Thickness	54.12	12.76	0.24
		Weight	324.34	200.09	0.62
	Rounded	Maximum Dimension	80.86	34.02	0.42
		Maximum Width	73.71	31.40	0.43
		Thickness	43.02	12.32	0.29
		Weight	291.30	281.00	0.96
	Indeterminate	Maximum Dimension	87.97	28.92	0.33
		Maximum Width	78.26	28.56	0.36
		Thickness	54.33	24.96	0.46
		Weight	339.47	297.96	0.88
Bipolar Core	Rounded	Maximum Dimension	46.03	0	0
		Maximum Width	43.6	0	0
		Thickness	20.24	0	0
		Weight	35.9	0	0

Table 4.53.2., provided the tabulation of maximum dimension, maximum width, thickness and weight of core types made from different clast types and how they are different between each other. As in Table 4.53.2., core which are made from sub-angular are longer (95.78 mm) and thicker (58.02 mm), at the same time when multi-platform core are made from indeterminate are wider (78.26 mm). When

weight is taken into account for the flake cores, flake core made from angular clast types are the heaviest (601.42 gms). While flake core made from rounded are the shortest (69.25 mm), thinnest (35.42) and lightest (206.17 gms), at the same time when these cores are made from sub-rounded clast types they are narrowest (61.72 mm). Whereas, blade cores which has the information on the cortex type were minimum in count (n=1), and they are made from angular clast type.

Hence, Table 4.53.2., indicates that flake core made from sub-angular and angular clast are bigger than flake core made from rounded and sub-rounded clast type. Blade core which had information on the cortex type were made from angular clast type.

Table 4.53.2. Mean, standard deviation and coefficient of variation for general metrical measurements of core types from different phases broken down by cortex type from Lakhmapur.

Core Type	Cortex Type	Variable	Mean	Std. Deviation	CV
Blade Core	Angular	Maximum Dimension	33.84	0	0
		Maximum Width	24.26	0	0
		Thickness	16.08	0	0
		Weight	16.6	0	0
Flake Core	Angular	Maximum Dimension	90.72	26.51	0.29
		Maximum Width	72.01	25.42	0.35
		Thickness	55.72	19.19	0.34
		Weight	601.42	766.10	1.27
	Sub-Angular	Maximum Dimension	95.78	15.46	0.16
		Maximum Width	76.02	19.96	0.26
		Thickness	58.02	15.47	0.27
		Weight	427.87	187.15	0.44
	Sub-Rounded	Maximum Dimension	77.80	19.45	0.25
		Maximum Width	61.72	15.53	0.25
		Thickness	54.12	12.76	0.24
		Weight	324.34	200.09	0.62
	Rounded	Maximum Dimension	69.25	31.35	0.45
		Maximum Width	63.67	28.20	0.44
		Thickness	35.42	15.78	0.45
		Weight	206.17	247.44	1.20
	Indeterminate	Maximum Dimension	87.97	28.92	0.33
		Maximum Width	78.26	28.56	0.36
		Thickness	54.33	24.96	0.46
		Weight	339.47	297.96	0.88

Influence of reduction stages on the variability observed in the core types

Cores are defined as intentionally knapped lithic artifacts from which useful flakes have been removed. A core is irreversibly reduced in mass when flakes have been removed from it. During this process the shape of core changes. Another way to understand the core reduction and its effect on the morphology of core, a number of variables are plotted against the core size. As reduction progress many characteristics of core show an increase, while other decrease.

Number of variables plotted against increasing core rotation. When number of variables was plotted against increasing core rotation, the total number of flake scar, number of platform perimeters on core increased with each rotation. Core with cortical platform has the least number of rotations and is followed by single conchoidal platform; whereas, multi conchoidal platform core has the highest number of rotation (Figure 4.53.1), indicative of stages of reduction. In the initial stage of reduction the core has cortical platform with minimum number of rotation and as the reduction proceeds, rotation increases with single conchoidal platform, further reduction results in multi conchoidal platform (prepared platform) with an increase in rotation from the previous ones (Figure 4.53.1). The count for non-feather termination (step and hinge) (Figure 4.53.2) and external angle of the last platform increase (Figure 4.53.3)as the rotation increases, indicative of less reduced core have fewer number of non-feather termination with low external platform angle and as the core is reduced considerably, the count of non-feather termination increases with high external platform angle. When rotation increases, number of platform quadrants also increases (Figure 4.53.4), indicating that as the reduction increase the platform perimeter was completely exhausted with high rotation in order to remove maximum number of flake from the core. One more interesting aspect was noticed, and that was, when the core was rotated many times, scar>15 mm (Figure 4.53.5), number of elongated parallel scar (Figure 4.53.6) and longest flake removed (Figure 4.53.7) from the core at first increases and then decreases as the rotation increases, this indicates that at initial stage of reduction elongated big flakes were removed and as the reduction proceeds the length of flake decreases. Whereas, cortex % diminishes gradually (Figure 4.53.8) with the decrease in **core size** (Figure 4.53.9) and in **weight** (Figure 4.53.10) as the rotation increases. This indicates that as reduction advances, the **maximum dimension** (Figure4.53.11),

maximum width (Figure4.53.12) and **thickness** (Figure4.53.13) decreases with the decrease in cortex % of the core.

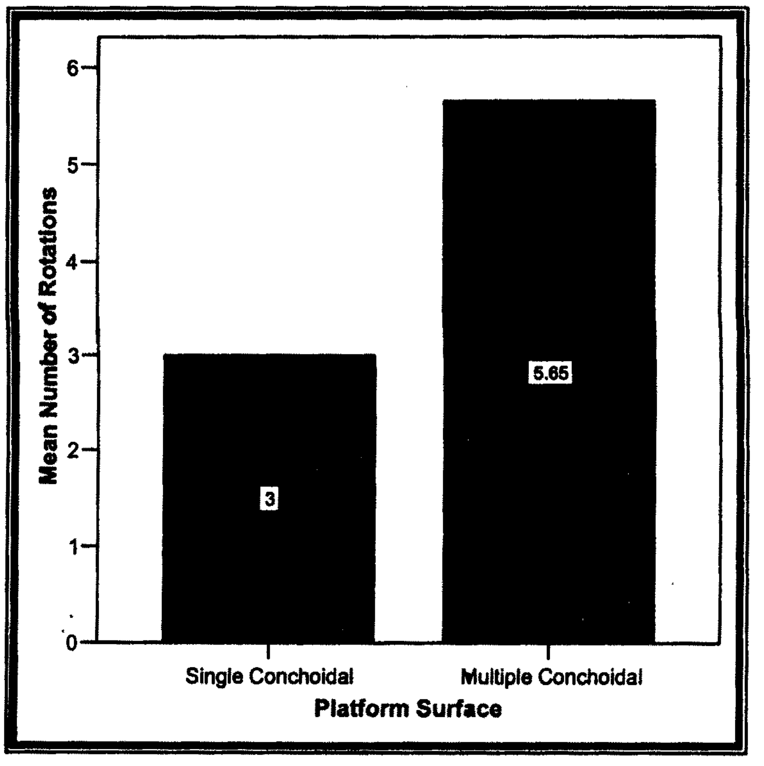

Figure4.53.1. Bar graph for number of rotation of core by platform surface from Lakhmapur.

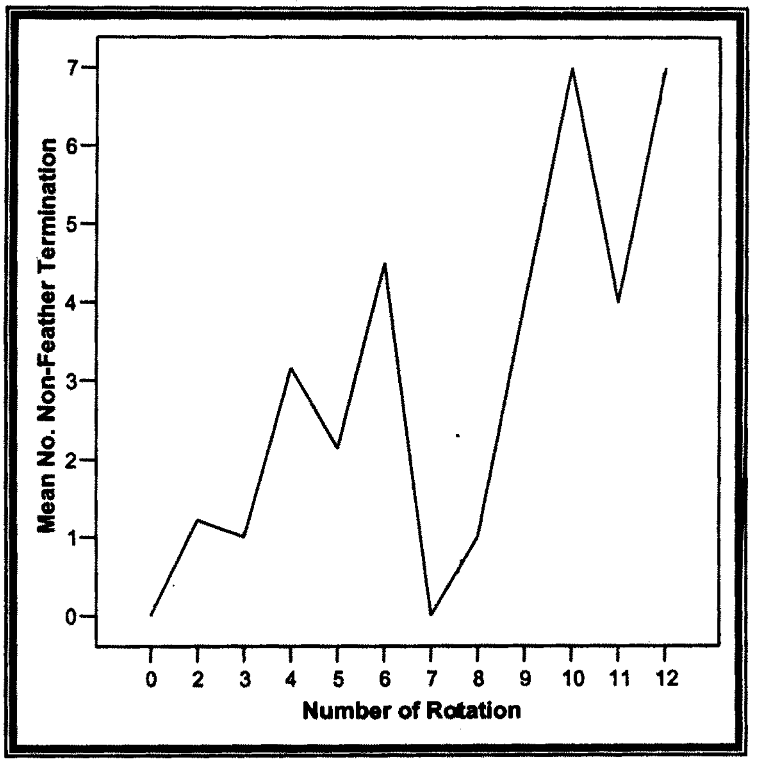

Figure 4.53.2. Line graph for number of rotation of core by total number of non-feather termination from Lakhmapur.

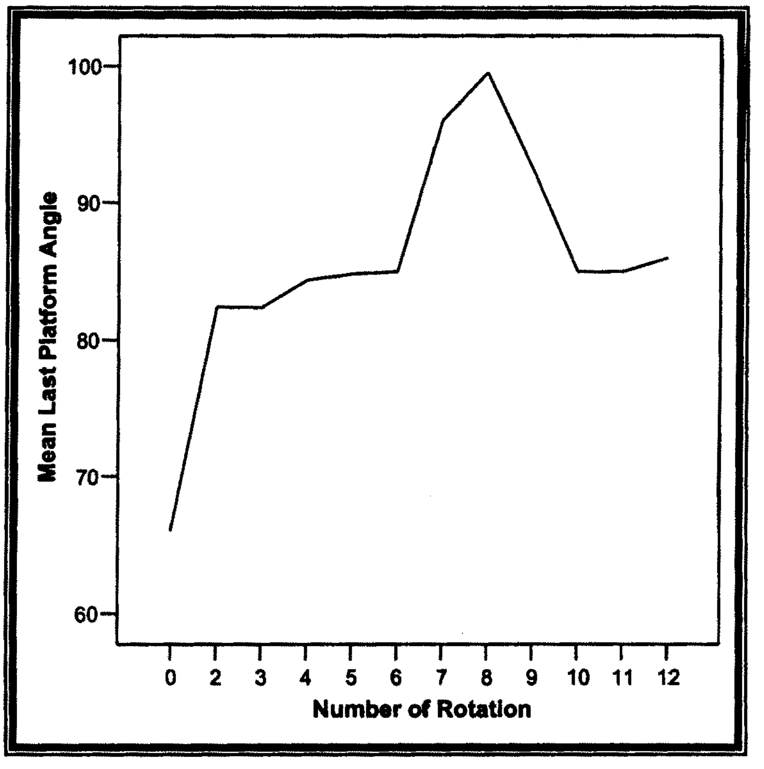

Figure 4.53.3. Line graph for number of rotation of core by last platform angle from Lakhmapur.

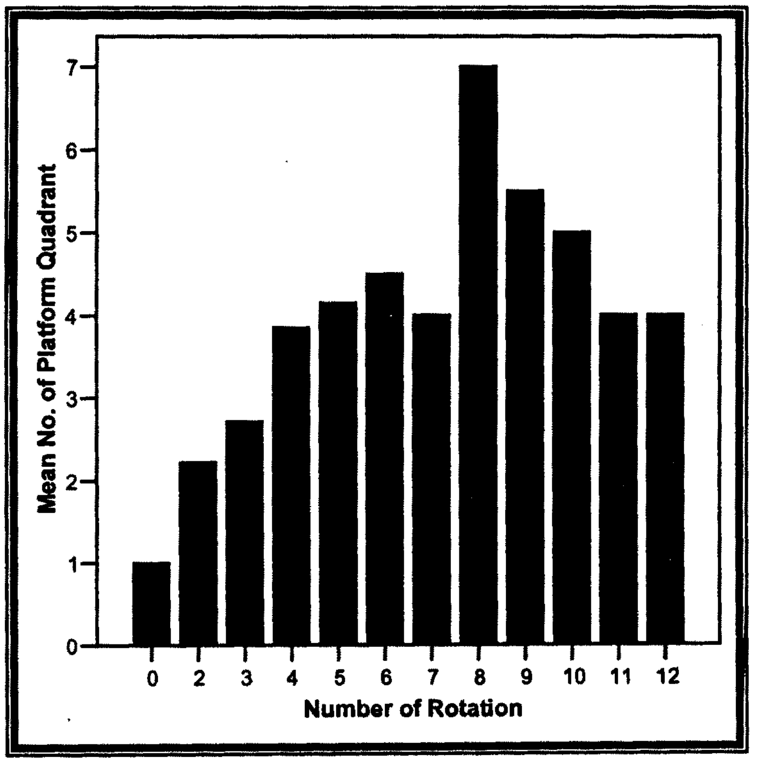

Figure 4.53.4. Bar graph for number of rotation of core by number of platform quadrants from Lakhmapur.

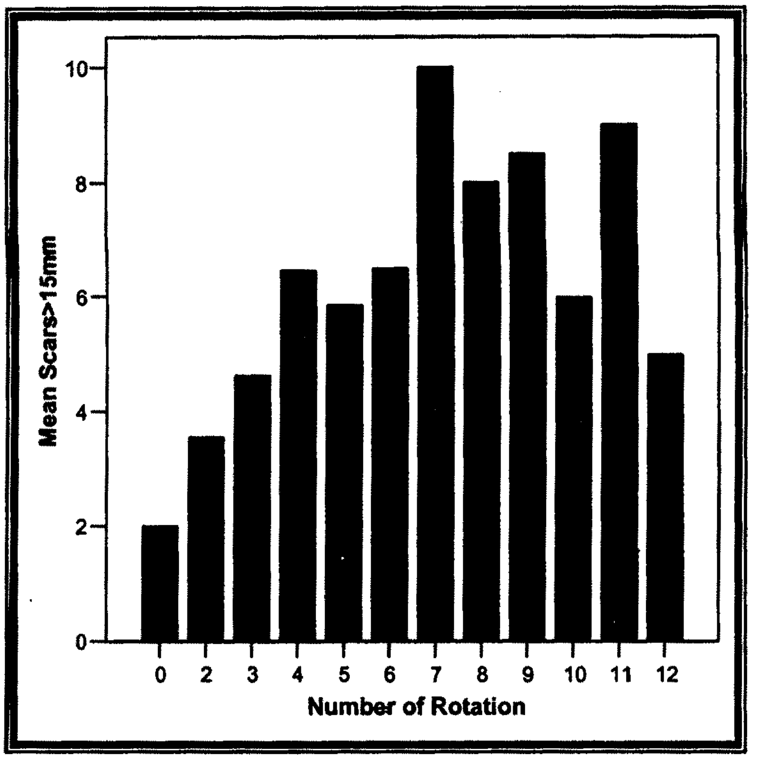

Figure 4.53.5. Bar graph for number of rotation of core by number of scars >15 mm from Lakhmapur.

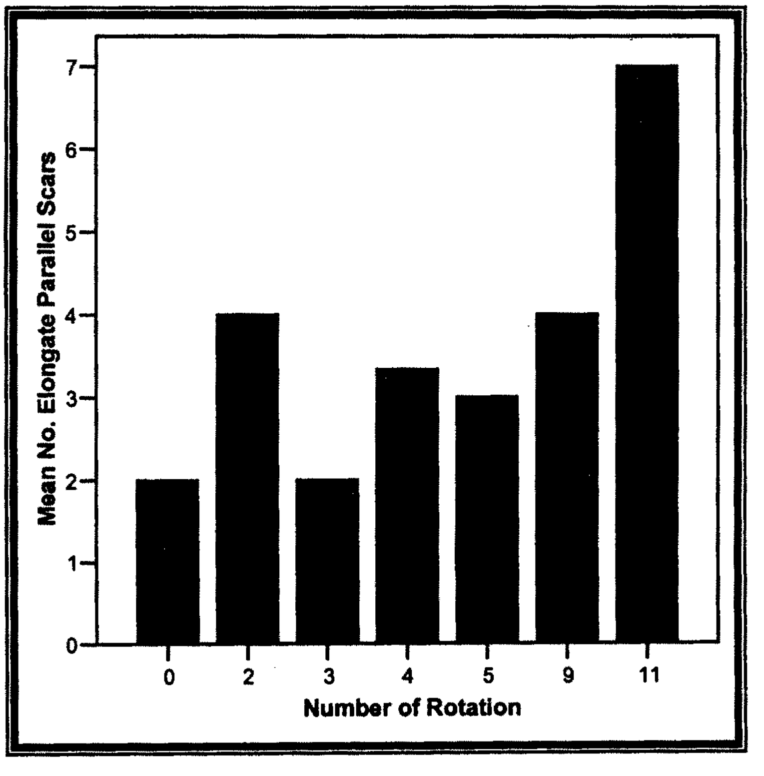

Figure 4.53.6. Bar graph for number of rotation of core by number of elongated parallel scars from Lakhmapur.

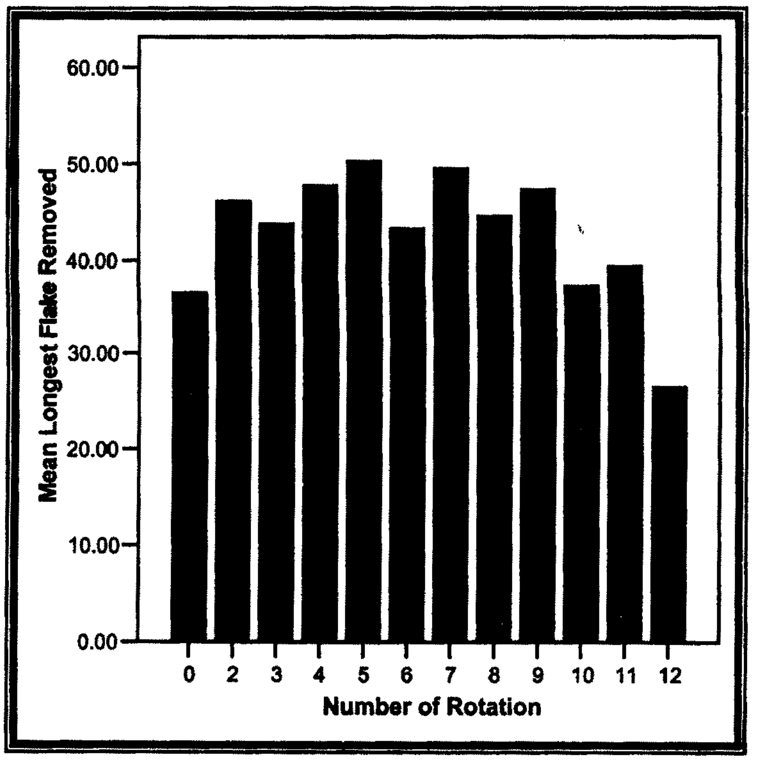

Figure 4.53.7. Bar graph for number of rotation of core by number of longest flake removed from Lakhmapur.

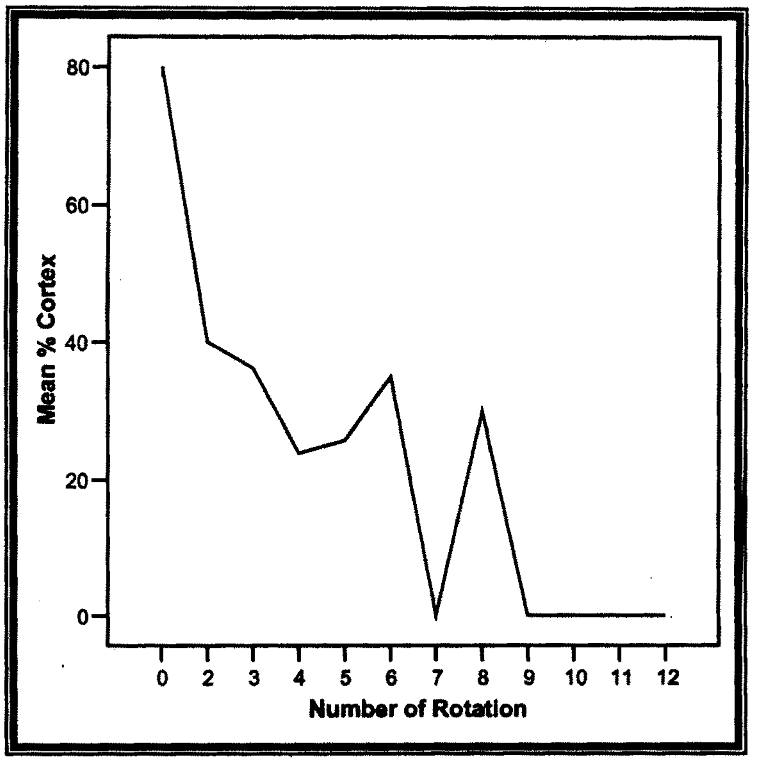

Figure 4.53.8. Line graph for number of rotation of core by cortex % from Lakhmapur.

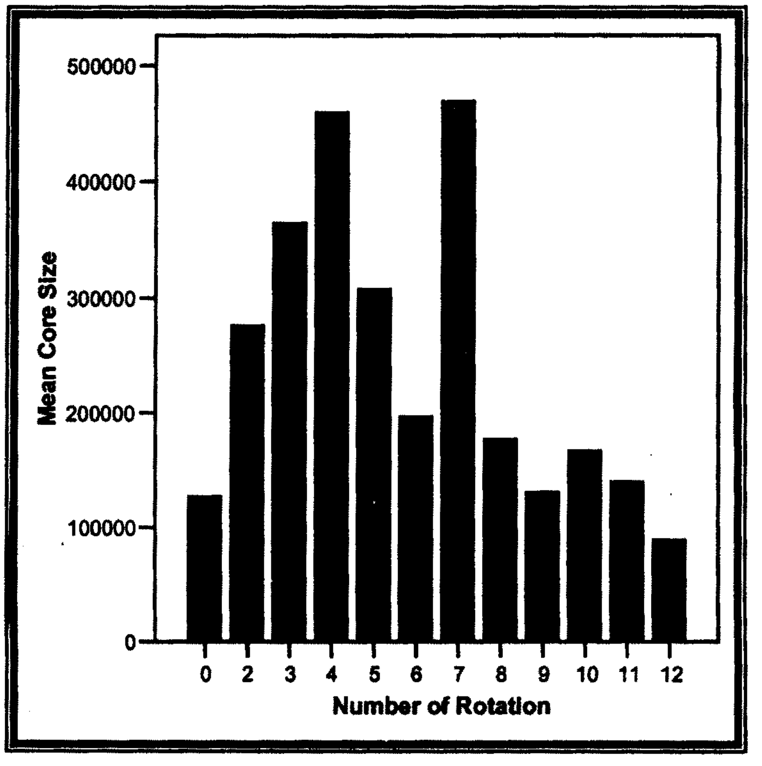

Figure 4.53.9. Bar graph for number of rotation of core by core size from Lakhmapur.

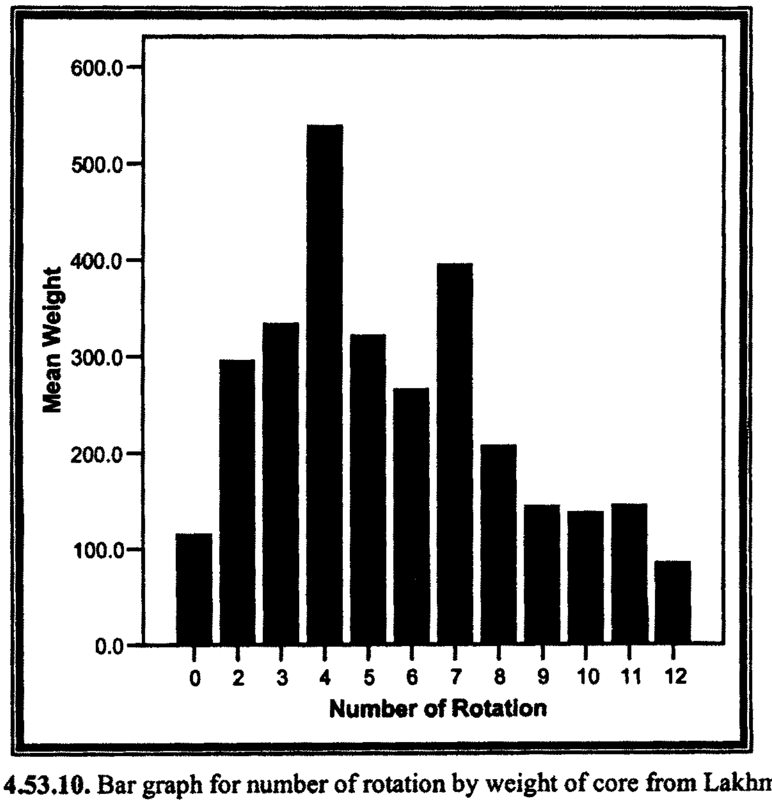

Figure 4.53.10. Bar graph for number of rotation by weight of core from Lakhmapur.

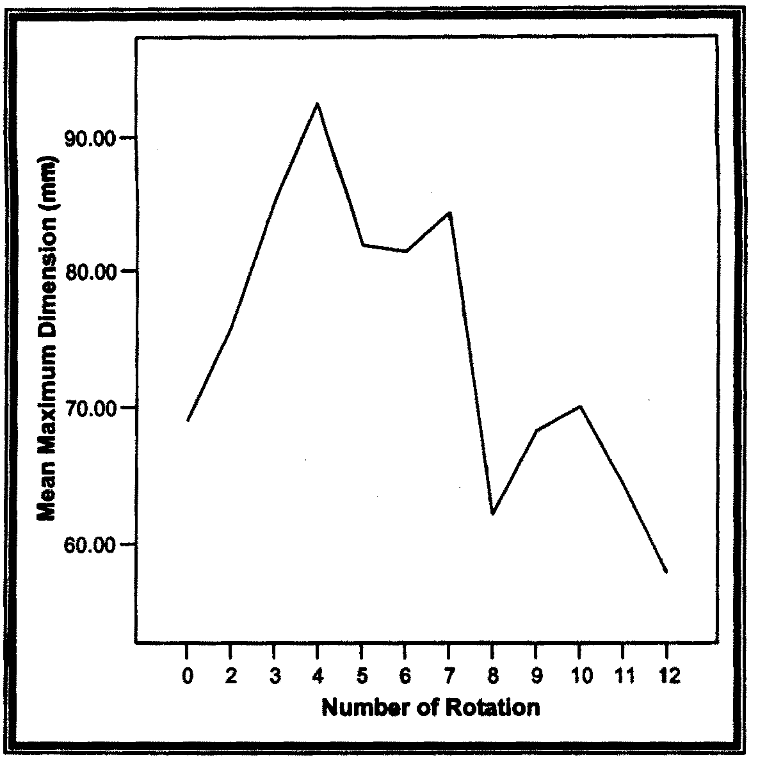

Figure 4.53.11. Line graph for number of rotation by maximum dimension of core from Lakhmapur.

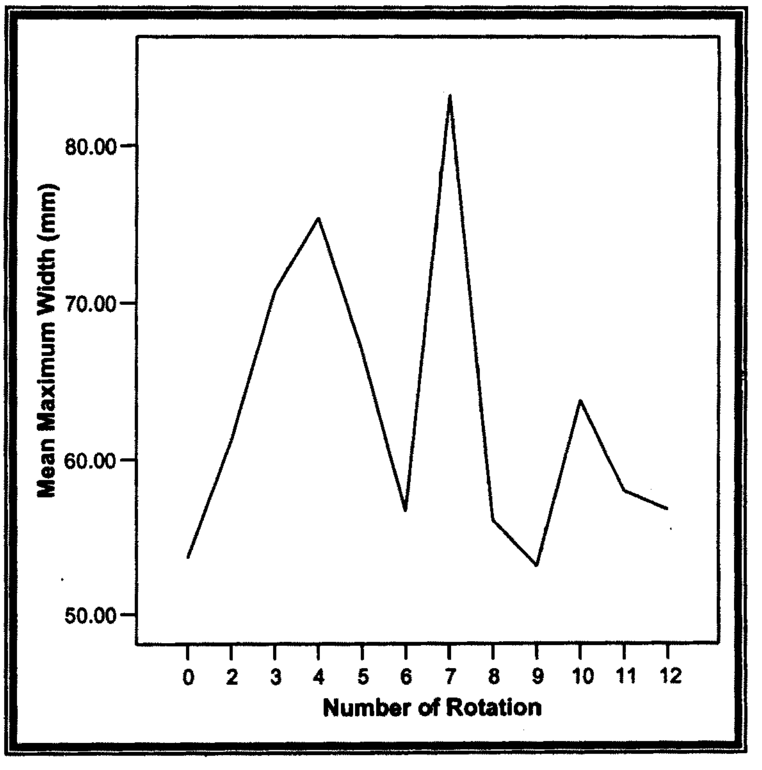

Figure 4.53.12. Line graph for number of rotation by maximum width of core from Lakhmapur.

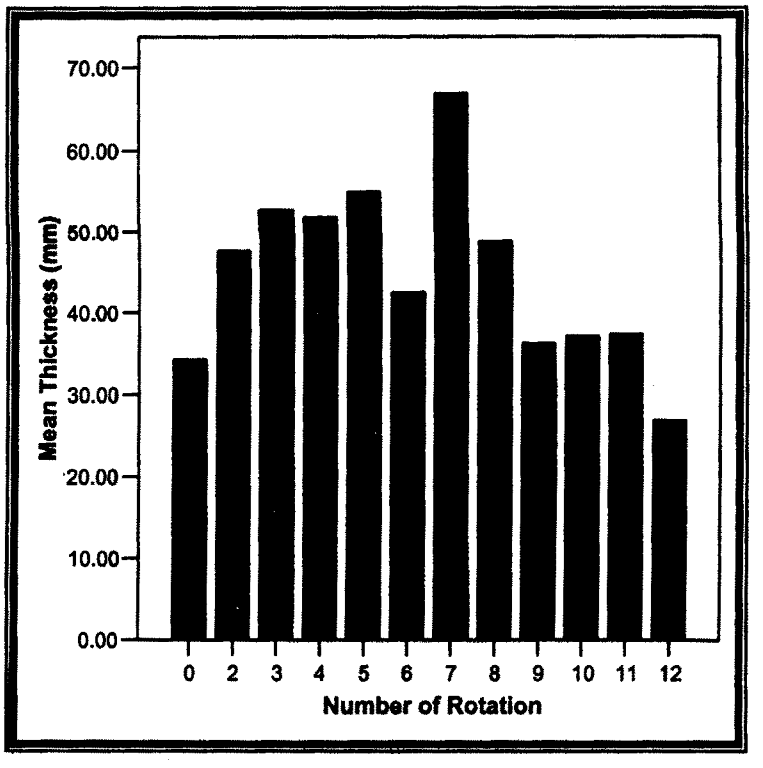

Figure 4.53.13. Bar graph for number of rotation by thickness of core from Lakhmapur.

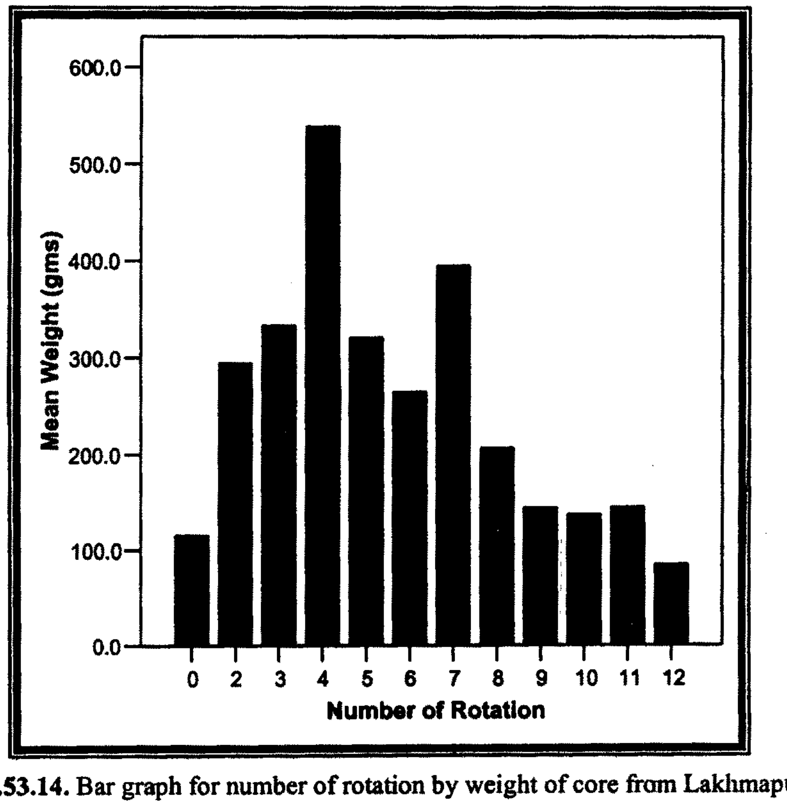

Figure 4.53.14. Bar graph for number of rotation by weight of core from Lakhmapur.

4.54. Retouched tool typology at Lakhmapur

This section will qualitatively and quantitatively explore retouched tools by analyzing its size and shape. Common metrical and non-metrical measurements are analyzed within and between the retouched tool types.

From this site a total of 27 retouched tool types were recovered from the excavation. Out of 27, 16 (59.3%) were scrapers, 7 (25.9%) were notched tool, 2 (7.4%) are borers, 1 (3.7%) is a point and 1 (3.7%) burin (Table 4.54.1).

Table 4.54.1. Frequency of retouched tools from Lakhmapur.

Retouched Tool Type	Frequency	Percent
Scraper	16	59.3
Notched	7	25.9
Borer	2	7.4
Point	1	3.7
Burin	1	3.7
Total	**27**	**100**

4.55. Non-metrical attributes recorded for retouched tool types

Common non-metrical attributes were recorded for cores (non-metrical are explained in the previous section as well as in the methodology section of this thesis). Simple bar, box plots and simple tables were used in order to explain these non-metrical attributes.

Raw material and grain size.

Table 4.55.1., provides tabulation for retouched tool types by raw material types. From Table 4.55.1 and 4.55.2., it is clear that the most preferred raw material at this site was quartzarenites (quartzite) (26) having 1/16 to 2 mm grain size than other raw material type i.e., chert breccia (1) having >2 mm grain size.

Table 4.55.1. Frequency of raw material types from Lakhmapur.

Raw Material	Frequency	Percent
Quartzarenites (quartzite)	26	96.3
Chert breccia	1	3.7

Total	**27**	**100**

Table 4.55.2. Frequency of grain size types from Lakhmapur.

Grain Size of Raw Material	Frequency	Percent
Arenaceous (1/16 to 2 mm)	26	96.3
Rudeaceous (>2 mm)	1	3.7
Total	**27**	**100**

Table 4.55.1., shows the retouched tool types (scraper, notched, borer, point and burin) by different raw material types from Lakhmapur. There are 27 retouched tools at this site as what was mentioned already in the same description and about raw material, there is a table above (see, Table 4.55.1) with detailed information on the raw material types and its grain size, but where else there was no information added about on which raw material these retouched tool types had manufactured. Hence, the Table 4.55.1., is here was added in order to show clearly about how many tools had manufactured on these both raw material types (quartzarenites and chert breccia). Out of these 27 retouched tools from Lakhmapur, only 16 were recognized as scraper, because remaining were 7 notched, 2 borer, 1 point and 1 burin and among them16 scrapers, 2 borers,1 point and 1 burin alone were made on quartzarenites (quartzite). Whereas, only one tool type i.e., notched (7) were made on both quartzarenites (quartzite) (6) and chert breccia (1) (Table 4.55.3).

Table 4.55.3. Retouched tool types broken by raw material from Lakhmapur.

Retouched Tool Type	Raw Material		Total
	Quartzarenites (quartzite)	Chert breccia	
Scraper	16	0	16
Notched	6	1	7
Borer	2	0	2
Point	1	0	1
Burin	1	0	1
Total	**26**	**1**	**27**

Table 4.55.4., provides information about retouched tool types and its grain size of raw material types from the site Lakhmapur. This Table 4.55.4., also shows clearly about those retouched tools which had manufactured on both raw material

which arenaceous (1/16 to 2 mm) and rudeaceous (>2 mm) types of grain size. It is clear from the same table about the total retouched tool count (27) collected from Lakhmapur. Out of these 27 retouched tools from Lakhmapur, 16 were recognized as scrapers and remaining were 7 notched, 2 borer, 1 point and 1 burin and among those retouched tool types, 16 scrapers, 2 borers,1 point and 1 burin alone were made on arenaceous type of grain size. Whereas, only one tool type which was made on both arenaceous (1/16 to 2 mm) (6) and rudeaceous (>2 mm) (1) types of grain size was notched (7).

Table 4.55.4. Retouched tool types broken by grain size from Lakhmapur.

Retouched Tool Type	Grain Size of Raw Material		Total
	Arenaceous (1/16 to 2 mm)	Rudeaceous (>2 mm)	
Scraper	16	0	16
Notched	6	1	7
Borer	2	0	2
Point	1	0	1
Burin	1	0	1
Total	**26**	**1**	**27**

4.56. General metrical measurements for retouched tool types

Variability between and within the retouched tool types (scraper, notched, borer, point and burin), is shown here with the help of table and comparison of general metrical measurements like maximum dimension, maximum width, thickness and weight.

As said previously, the retouched tools from Lakhmapur are 27 in counts and among them scrapers are 16, notched are 7, borers are 2, point was 1 and burin was 1. From these types, point was the longest (77) and widest (62.52) tool type than the others. But, borer on the other hand was the thickest (22.63) tool type than point and other tools from Lakhmapur. About scrapers which fall into the second largest tool type, was the heaviest (94.41) among all others like point, borer, notched and burin. Whereas, burin was the shortest (29.43), narrowest (19.56), thinnest (8.72) and lightest (4.6) among the retouched tool types (see, Table 4.56.1).

Table 4.56.1. Mean, standard deviation and coefficient of variation of general metrical measurements for retouched tool types from different sites at Lakhmapur.

Retouched Tool Type	Variable	Mean	Std. Deviation	CV
Scraper	Maximum Dimension	66.97	25.30	0.38
	Maximum Width	52.87	18.06	0.34
	Thickness	20.67	9.48	0.46
	Weight	94.41	93.23	0.99
Notched	Maximum Dimension	46.31	5.48	0.12
	Maximum Width	33.76	7.93	0.23
	Thickness	12.61	1.83	0.15
	Weight	19.76	7.67	0.39
Borer	Maximum Dimension	49.36	24.17	0.49
	Maximum Width	45.08	17.84	0.40
	Thickness	22.63	0	0
	Weight	39.1	43.70	1.12
Point	Maximum Dimension	77	0	0
	Maximum Width	62.52	0	0
	Thickness	18.07	0	0
	Weight	79.7	0	0
Burin	Maximum Dimension	29.43	0	0
	Maximum Width	19.56	0	0
	Thickness	8.72	0	0
	Weight	4.6	0	0

4.57. Additional metrical measurements for retouched tool types

The variability between the two retouched tool types are shown with the help of table and by the additional measurements like retouch length, length of margin, retouch depth, index of edge curvature and Clarkson index of invasiveness.

Scrapers from Lakhmapur has higher mean value and standard deviation in retouch length (56.9 mm), length of margin (154.51 mm), retouch depth (12.31 mm), index of edge curvature (0.12 mm) and Clarkson index of invasiveness (0.21 mm) than the notched tools from the same region with lower mean value in retouch length (29.92 mm), length of margin (107.65 mm), retouch depth (3.05 mm), index of edge curvature (0.05 mm) and Clarkson index of invasiveness (0).

Table 4.57.1. Mean, standard deviation and coefficient of variation of additional metrical measurements for retouched tool types from different sites at Lakhmapur.

Retouched Tool Type	Variable	Mean	Std. Deviation	CV
Scraper	Retouch Length	56.91	32.85	0.58
	Length of Margin	154.51	64.02	0.41
	Retouch Depth	12.31	14.09	1.14
	Index of edge Curvature	0.12	0.16	1.32
	Clarkson Index of Invasiveness	0.21	0.16	0.76
Notched	Retouch Length	29.92	0	0
	Length of Margin	107.65	0	0
	Retouch Depth	3.05	0	0
	Index of edge Curvature	0.05	0.07	1.41
	Clarkson Index of Invasiveness	0	0	0

4.58. Assessing variability within retouched tool types

Influence of raw material on the variability observed in the retouched tool types

From Table 4.58.1., it is clear that the retouched tool types (i.e., scraper, borer, point and burin) that were collected from Lakhmapur were made on same raw material type (i.e., quartzarenites), but notched was the only retouched tool type which was made from two different raw material types like quartzarenites (quartzite) and chert breccia. They also vary in maximum dimension, maximum width, thickness and weight when they made comparison between and within the retouched tool types by applying general metrical measurements. Points from this site are longer (77 mm) and wider (62.52 mm) than all other tools. Whereas, borers on the other hand is thicker (22.63 mm), but shorter (49.36 mm), narrower (45.08 mm) and lighter (39.1mm) than the points which was thinner (18.07 mm) and lighter (79.7 mm). Scrapers which falls under the second largest (66.97 mm), widest (52.87 mm) and thickest (20.67) tool type category, are heavier (94.41) than other tool types. Notched tools made from quartzarenites (quartzite) are longer (46.14 mm), wider (31.59 mm), thicker (12.51 mm) and heavier (19 mm) than burin, but they (i.e., notched and burin) are shorter, narrower, thinner and lighter than other tool types. But among them (i.e., notched and burin), burin were shorter (29.43 mm), narrower (19.56 mm), thinner (8.72 mm) and lighter (4.6 mm) than all other retouched tool types from Lakhmapur. At the

same time notched tools made from chert breccia are longer (47.37 mm), wider (46.81 mm), thicker (13.19 mm) and heavier (24.3 mm) than the notched tool made on quartzarenites (quartzite).

Table 4.58.1. Mean, standard deviation and coefficient of variation of general metrical measurements for retouched tool types by raw material types from different sites at Lakhmapur.

Retouched Tool Type	Raw Material	Variable	Mean	Std. Deviation	CV
Scraper	Quartzarenites (quartzite)	Maximum Dimension	66.97	25.30	0.38
		Maximum Width	52.87	18.06	0.34
		Thickness	20.67	9.48	0.46
		Weight	94.41	93.23	0.99
Notched	Quartzarenites (quartzite)	Maximum Dimension	46.14	5.98	0.13
		Maximum Width	31.59	5.98	0.19
		Thickness	12.51	1.98	0.16
		Weight	19.00	8.11	0.43
	Chert breccia	Maximum Dimension	47.37	0	0
		Maximum Width	46.81	0	0
		Thickness	13.19	0	0
		Weight	24.3	0	0
Borer	Quartzarenites (quartzite)	Maximum Dimension	49.36	24.17	0.49
		Maximum Width	45.08	17.84	0.40
		Thickness	22.63	0	0
		Weight	39.1	43.70	1.12
Point	Quartzarenites (quartzite)	Maximum Dimension	77	0	0
		Maximum Width	62.52	0	0
		Thickness	18.07	0	0
		Weight	79.7	0	0
Burin	Quartzarenites (quartzite)	Maximum Dimension	29.43	0	0
		Maximum Width	19.56	0	0
		Thickness	8.72	0	0
		Weight	4.6	0	0

Testing reduction model to explain the variability within the retouched tool types

Most studies of reduction continuums for retouched implements have remained locked within normative typological schemes. This is best seen in the analyses of changing implement morphology that are undertaken through comparison of measures of central tendency between the type classes themselves, rather than using individual specimens removed from a typological framework (Clarkson, 2002).

As reduction increases number of aspects of flake morphology changes and these changes depicts reduction continuums in retouched flakes. This was

documented in order in the present study. This analysis is undertaken for scrapers (i.e. retouched flakes), retouched tabular pieces, notched tools, burin and points.

Measuring retouched tool reduction

In order to measure the intensity of reduction, Clarkson's and Kuhn's method of measuring intensity of on retouched flakes.

Perimeter of Retouch

The proportion of the worked perimeter of an artifact might also be expected to increase if new and adjacent edges are used and resharpened as existing ones are exhausted. This was tested by using the Clarkson's Index of Invasiveness and Kuhn's Index of Invasiveness. Figure 4.58.1. and 4.58.2., explains the relationship between perimeter retouch with index of invasiveness. When more perimeter of an artifact is worked, index of invasiveness value increases.

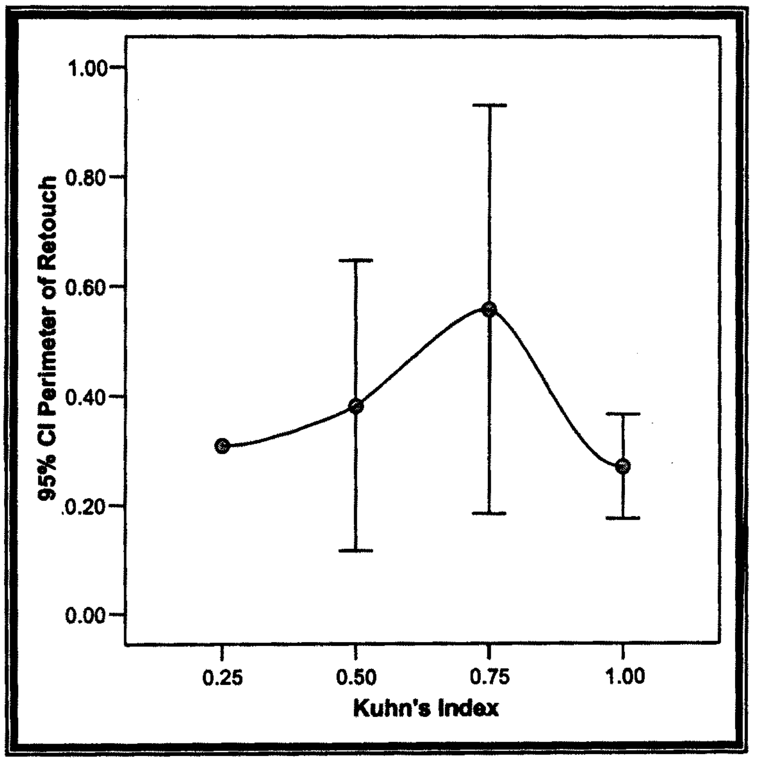

Figure 4.58.1. Error bar plot of Kuhn's index of invasiveness by perimeter retouch for retouched tools from Lakhmapur.

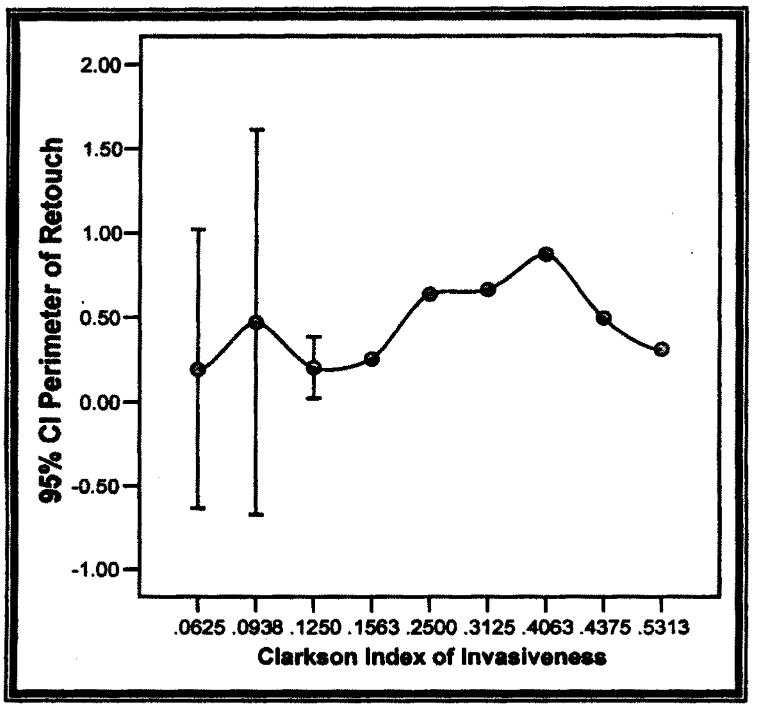

Figure 4.58.2. Error bar plot of Clarkson's index of invasiveness by perimeter retouch for retouched tools from Lakhmapur.

Edge Angle:

Edge angle was recorded at the same three locations where retouch height and flake thickness were taken for measurement in Kuhn's GIUR. Figure 4.58.3., is a error plot to show the relationship between mean edge angle and index of invasiveness. This figure explains that as the invasiveness value increases the mean edge angle also increases over the reduction sequence.

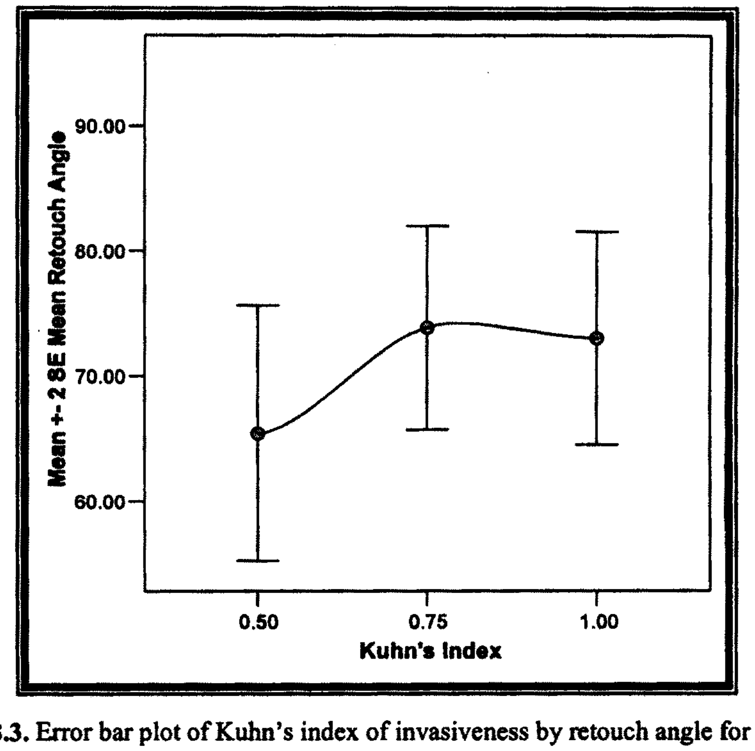

Figure 4.58.3. Error bar plot of Kuhn's index of invasiveness by retouch angle for retouched tools from Lakhmapur.

Edge Curvature

As retouch intensity increases on the perimeters of the retouched tools, it might be expected that the retouched edge should become more curved. Edge curvature is here calculated by dividing the depth of retouch by its diameter as outlined in Chapter I (in methodology section). Using this technique, concave edges give a negative result while convex edges yield a positive one. Figure 4.53.5., indicates that edges start out slightly convex till the 4th category and then starts to concaving as the perimeter retouched increases. When the reduction comes into the 5th category it becomes highly concave. Figure 4.53.4 and 4.53.5., shows that as the Clarkson's and Kuhn's index increases the index of edge curvature increases and at the 2nd in Kuhn's and in 4th stage of Clarkson's index value category it reaches a peak and then falls, indicating that, as when the retouch increases, the specimen becomes convex to concave (Figure 4.53.5), same aspect is noticed when the index of invasiveness increases, index of edge curvature starts to fall (Figure 4.53.4 and 4.53.5). This is indicative of, as retouch increase with increases in % of perimeter retouch, results in convex edge of the specimen becoming concave.

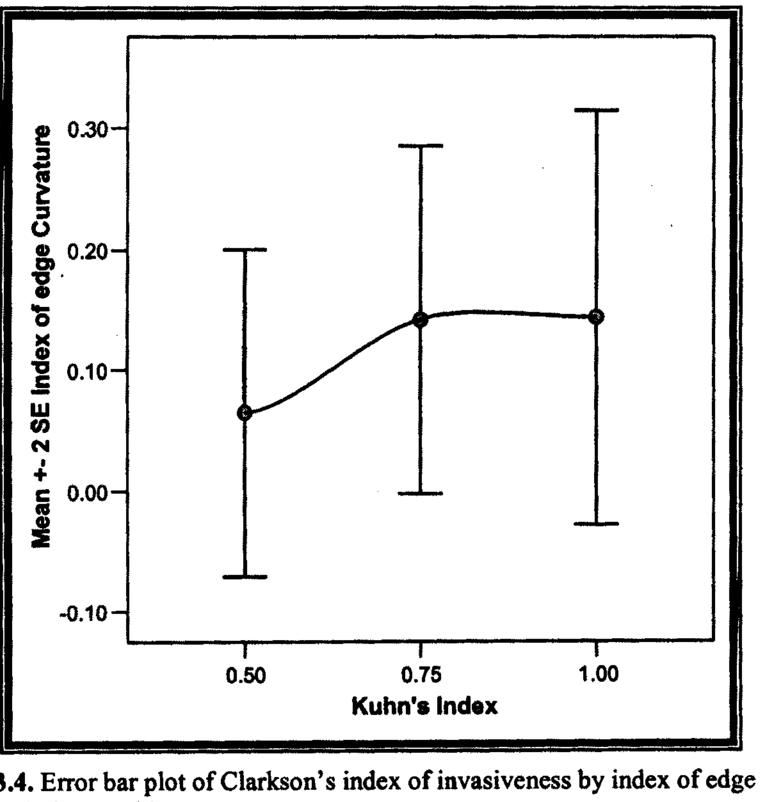

Figure 4.53.4. Error bar plot of Clarkson's index of invasiveness by index of edge curvature for retouched tools from Lakhmapur.

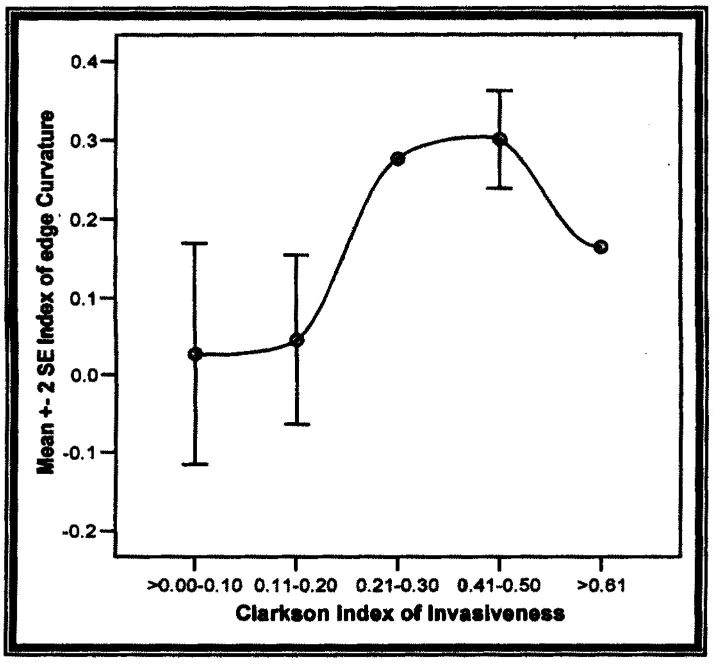

Figure 4.53.5. Error bar plot of Clarkson's index of invasiveness by index of edge curvature for retouched tools from Lakhmapur.

Morphological Changes

In the following analysis, artifact weight is plotted against the Index of invasiveness for unifacial and bifacial. Figure 4.53.6., is an error bar plot for weight of retouched tool against the Kuhn's index of invasiveness. Figure 4.53.7., is an error bar plot for weight of retouched tool against the Clarkson's index of invasiveness. Both figures indicate that retouched tools become progressively lighter as retouching continues, and the weight becomes constant at a stage were no reduction could take place. More variation exists in lightly reduced retouched tools than heavily reduced ones.

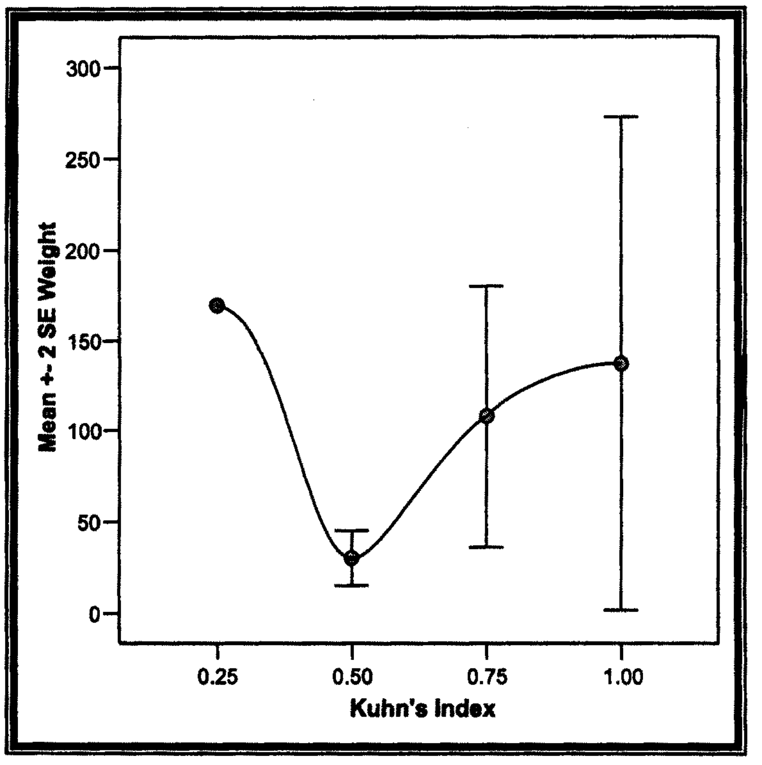

Figure 4.53.6. Error bar plot of Kuhn's index of invasiveness by weight for retouched tools from Lakhmapur.

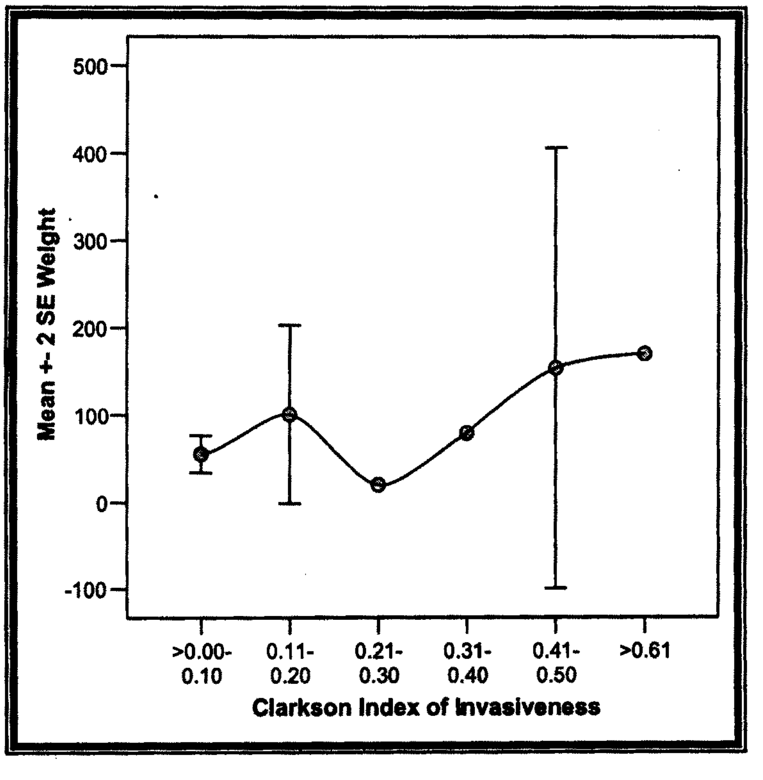

Figure 4.53.7. Error bar plot of Clarkson's index of invasiveness by mean weight for retouched tools from Lakhmapur.

In the following analysis, artifact width/thickness is plotted against the Index of invasiveness for unifacial and bifacial. Figure 4.53.8., is an error bar plot for width/thickness of retouched tool against the Kuhn's index of invasiveness. As the index increase, width/thickness value decreases with variations. In the first stage of reduction the retouched tools have the original thickness at the lateral margins and as the reduction progress it gets thicker due to removal of flake from the lateral margins while, as the reduction progress into the last stage it stops getting thicker. In the first stage of reduction the retouched tools retains the original thickness and as the reduction progress the edges become thicker.

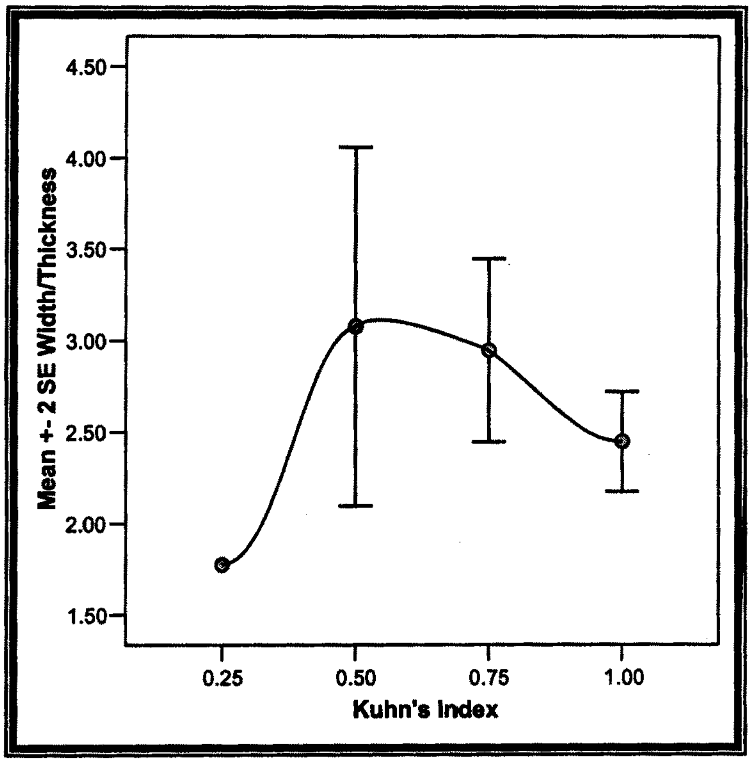

Figure 4.53.8. Error bar plot of Kuhn's index of invasiveness by mean refinement (width/thickness) for retouched tools from Lakhmapur.

In the following analysis, artifact cortex is plotted against the index of invasiveness and mean retouch angle for unifacial and bifacial. Figure 4.53.9 and 4.53.10., is an error bar plot for cortex % of retouched tool against the mean retouch angle, and Clarkson's & Kuhn's index of invasiveness. Figure 4.53.9., indicates that as index of invasiveness increases, cortex % decreases with variation within them. In the first stage of reduction the cortex % decreases gradually and in the next stage of reduction the cortex % stops decreasing and starts increasing (at the 5th index of invasiveness category, i.e., Clarkson's index category=0.41-0.50 to >0.61). The increase in the cortex % from the 5th category of invasiveness indicates that the

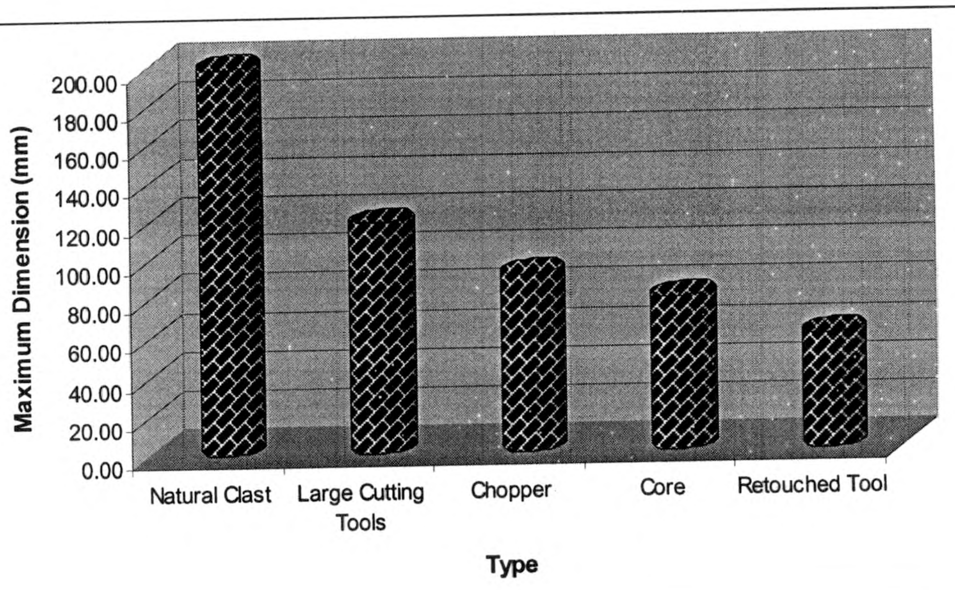

Figure 4.58.1. Bar graph for maximum length of natural clast type and flaked piece types.

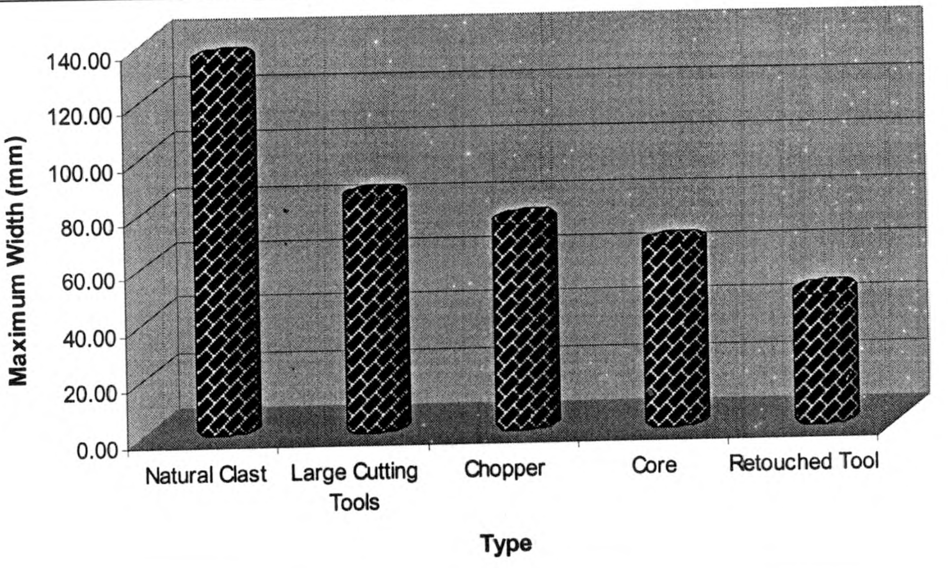

Figure 4.58.2. Bar graph for maximum width of natural clast type and flaked piece types.

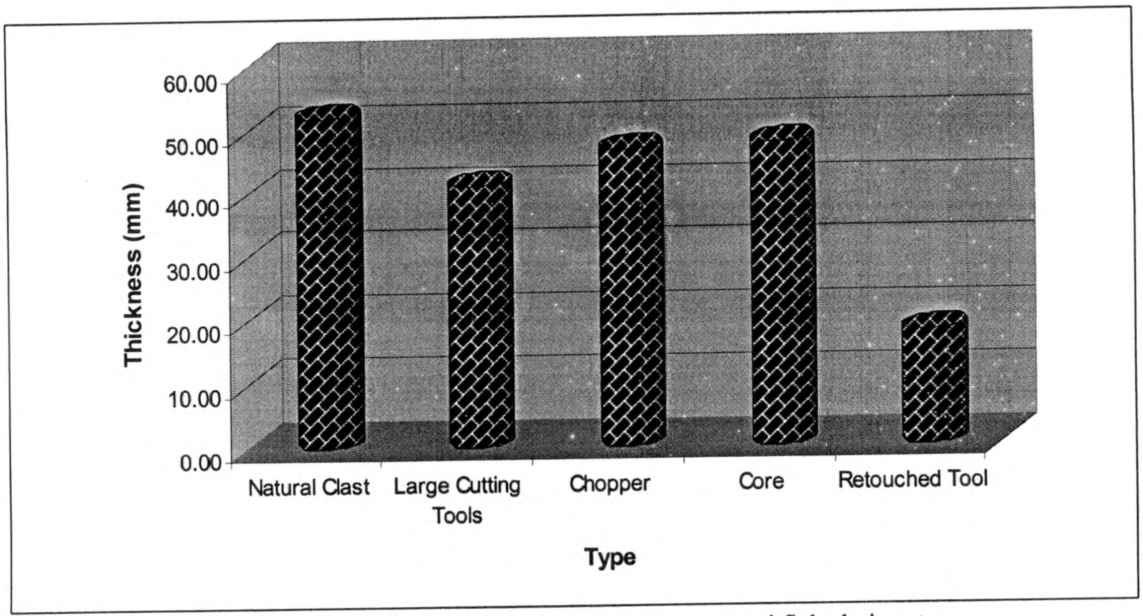

Figure 4.58.3. Bar graph for thickness of natural clast type and flaked piece types.

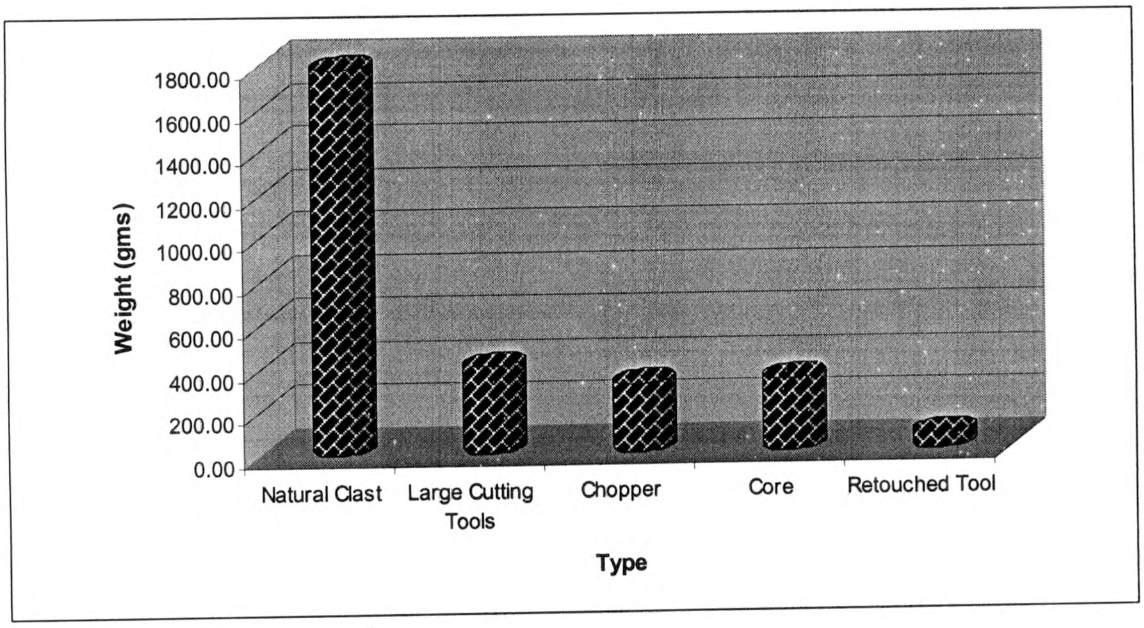

Figure 4.58.4. Bar graph for weight of natural clast type and flaked piece types.

4.59. Summary

This chapter investigated intra-assemblage stone tool morphological variability, and compared this variability to raw material properties. According to the method of Residuals (Isaac 1986) knowledge of outcrop form can be used to predict stone tool morphology and typology. Using the method of Residual approach several sections were examined which may contribute to assemblage variation.

Do outcrop forms for different raw material types dictate artifact form? This question was addressed with the help of cortex type present on the large cutting tools and by studying the initial form. The preference for angular cortex type for manufacturing large cutting tools explains that the hominins exploited rock directly from outcrop which is located in Kaladgi formation from all the three sites namely Khyad, Benkaneri and Lakhmapur. In addition to the angular clast type rounded clast types were used from the site Khyad which must have been collected from the fans which were coming from the hills of Kaladgi formation to the plains where the present river is flowing and the hominins at this site did not preferred to use water-worn rocks. The more exploitation of angular clasts than other clast types from this region is because of two main reasons and they are-

- lack of rounded clasts at this site is caused by the short distance of transportation of angular clasts from the elevated place (hills) to the plains (site is situated on the plain) and
- these angular clasts have natural angular edges which guided flake detachment. The hominins at this site used these angular edges to their advantage in order to manufacture large cutting tools.

In the manufacturing of large cutting tools, flake is the dominant initial form from all the three sites namely Khyad, Benkaneri and Lakhmapur. The dominance of flake with more of angular cortex type as initial form implies that hominins most often exploited rocks directly from outcrops or from the colluvial fan deposit.

From this region quartzarenites (quartzite) was the most preferred raw material for manufacturing large cutting tools, because it has 1/16 to 2 mm grain size and are homogeneous in nature, this homogeneity tends to make knapping easier and these quartzarenites (quartzite) are locally available. In order to fetch this kind of raw material, hominins made repeated visits to the outcrops. The absence of

debitage from Khyad, indicates that these artifacts which were collected were not manufactured at the same place where they were found. The hominins must have made blanks near the outcrop (which is <2km away from this site) and brought them for further reduction, whereas, the presence of debitage in large quantity from Benkaneri and Lakhmapur site indicates that these large cutting tools were manufactured at this site itself.

Size and shape variability:

This section has investigated the relationships between tool type and raw material type relative to inter-assemblage large cutting tool size and shape differences. When large cutting tools from Benkaneri are compared with large cutting tools from Khyad and Lakhmapur, large cutting tools from Benkaneri are narrower, thicker and lighter than large cutting tools from other sites, suggesting that the Benkaneri site was a quarry site, where the hominins made large cutting tool. Large cutting tools from Lakhmapur were shorter, thinner and lighter than large cutting tools from Khyad. Large cutting tools from Khyad were mare elongated, broader and thinner than large cutting tools from other two sites. When large cutting tools were sub-divided by tool type, significant differences in breadth/length, breadth1/breadth3 and thickness/breadth and thickness1/thickness3 ratios were observed. Cleavers generated differences in breadth/length and breadth1/breadth3 from all the three sites. As quartzarenites (quartzite) were the majority of raw material used from all the three sites to manufacture large cutting tools no statistical test could be preformed to see the effect of raw material on the large cutting tool variability. When large cutting tool were subdivided by cortex type and initial forms it gave a significant differences in maximum dimension, maximum width and thickness were observed. Large cutting tools made from flakes were thinner than the large cutting tools made from cobble, slab or blocky forms. Same kinds of inferences were obtained when large cutting tool's index ration like elongation, edge shape and refinement were compared with cortex type. In order to explain the variability present within these large cutting tools, a reduction model was applied, in which the tip length was compared with various indices which were generated by dividing breadth/length, breadth1/breadth3 and thickness/breadth and thickness1/thickness3. When the tip length was combined with different ratios of index, following conclusions were generated, they are as follows-

- Pointed large cutting tools have high tip length and are less refined.
- Broader large cutting tools have low tip length and are more refined than pointed large cutting tools.

The above statement indicates that as reduction increases pointed large cutting tools become broader and thinner. The variability within large cutting tools are explained by the result of increase of reduction.

Another way of explaining the variability was to form a hypothesis and in this hypothesis it was assumed that handaxes were made from axe blanks and cleavers were made from cleaver blanks. The information that were generated from the comparisons made between axe blank with handaxes and cleaver blank with cleavers resulted in following inferences-

- as the reduction increases the tip length of handaxe increases with decreasing base length,
- as the reduction increases the tip width becomes narrower with less variation in them,
- as the reduction increases the mid width value for axe blank decreases. But the mean value of handaxe (83.06) is marginally lower than axe blank (84.38), suggesting less reduction on the mid portion of the specimen.
- as reduction increases the base width of axe blank decreases,
- as reduction increases edge shape ratio decreases i.e., narrower specimens becomes broader,
- as reduction increases elongation index decreases i.e., longer specimens becomes shorter and
- as reduction increases refinement ratio also increases i.e., thicker specimens becomes thinner

At this site majority of large cutting tools were made from quartzarenites (quartzite) and other raw materials were extremely rare. In order to find the effect of shape and size of raw material on large cutting tool variability within the assemblage, cortex type and initial forms were used. Blocky and cobbles are excluded from this study because of low count. Handaxe made on slab are much

longer, wider and thicker than flake and indeterminate from all the three siets. Cleavers made on indeterminate are longer and thicker than cleavers made on flake; whereas cleaver made on flakes are wider and thinner. Biface made on indeterminate are longer, wider and thicker than biface made on flakes.

From all the three sites handaxe which are made from flakes are broader and refined than handaxes made from slab and indeterminate. When handaxe is compared with axe blank, handaxes are shorter, broader and thinner with less base length and tip length value. Cleavers are longer, broader and thicker with less base length and high tip length, whereas cleaver blanks are shorter, narrower, and thinner with high base length and low tip length value. Cleavers are similar to each other in elongation, refinement and base length. Biface made from flakes are shorter, narrower and are more refined than indeterminate.

Cores and retouched tools were only collected from Benkaneri and Lakhmapur. From Khyad not even a single core or retouched tool were collected, this might be due the preference of collection, so the absence of core and retouched tools should be taken cautiously. Majority of cores and retouched tools from Khyad, Benkaneri and Lakhmapur were made from quartzarenite. Cores and retouched tool look similar to each other from Benkaneri and Lakhmapur. From both the sites maximum dimension, maximum width, thickness and weight were almost similar to each other. All additional metrical measurements were also almost similar to each other.